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TEXT-BOOK

OF

GENERAL BOTANY.

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TEXT-BOOK

OF

GENERAL BOTANY.

BY

DR. W. J. BEHRENS.

TRANSLATION FROM THE SECOND GERMAN EDITION.

REVISED BY

PATRICK GEDDES, F.R.S.E.,

DEMONSTRATOR OF BOTANY IN THE UNIVERSITY OF EDINBURGH.

WITH FOUR HUNDRED AND EIGHT ILLUSTRATIONS.

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PREFACE TO THE ENGLISH EDITION.

To introduce to the English student a text-book which has so rapidly attained wide circulation and usefulness throughout the schools and colleges of the German-speaking countries, little preface or eulogium is necessary. The Author's aim has been twofold: he has endeavoured not only to explain in the simplest language the elementary facts of Vegetable Anatomy and Histology, of Physiology and Classification, but also to awaken the interest and enthusiasm of the student from the very outset, by introducing him to the fresher fields of the science, and by setting before him many of the latest and most interesting results of their exploration; so placing him, as the title of the original work has it, "at the newest stand-point of the science." In this relation, it is only necessary to refer to Part III., or, more particularly, to the section on the Fertilisation of Flowers, from which the reader can at once proceed to the original classics of Darwin and Müller, of Delfino and Hildebrand, and even face the unsolved problems which wait beyond.

In the systematic portion, the student will find the difficulty of mastering the Natural Orders diminished in practice by the help of the Analytical Tables at the end of the book, and even more by the broad and simple grouping of the Orders into their larger alliances. The postponement of the section dealing with the Cryptogams, until the requisite

knowledge of microscopic structure has been obtained, and the exposition of their relation to Phanerogams, will also be found useful.

The qualities of the translation appear to me as little in need of advertisement as those of the original, and I need only say, that its reconciliation of accuracy with freedom, of letter with spirit, are by no means due to the trifling verbal changes of my revisal, but to the conscientious and appreciative labours of Miss HARRIS SMITH.

PATRICK GEDDES.

BOTANICAL LABORATORY,
UNIVERSITY OF EDINBURGH, *April* 1885.

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INTRODUCTION.

ALL objects to be found in the world are either artificial or natural. *Artificial* objects are such as have been made by man with the hand, or by the aid of tools or machinery, from the raw material afforded by nature. *Natural* objects exist independent of human interference.

The science which treats of natural objects is termed *Natural History*. Natural History classifies natural objects under three heads:—*Minerals*, *Plants*, and *Animals*. The minerals (stones, metals, &c.) are *inanimate*; they are solid and homogeneous throughout, immutable in quantity, and not subject to cyclical change. Plants and animals are *animate* or *living beings;* for the performance of the functions of life they are endowed with instruments in the shape of *organs*, and are accordingly characterised by the name of *organisms*. An organism is said to be alive when it is possessed of certain *vital properties*. The vital properties common to all organisms are *growth* and the power of producing new organisms, or *reproduction*.

The difference between plants and animals consists in this, that animals, besides organs for growth and reproduction, are possessed of organs specialised for *sensibility*. Moreover, most animals have power to move about from place to place, or the power of *voluntary locomotion*. In plants there are no organs of sensibility or voluntary locomotion.

With regard to this subject, Linnæus, the Swedish naturalist (fl. 1750), says:—"Plants grow and live; animals grow, live, and feel." This, however, only applies to the more fully developed or higher animals or plants, for among the less fully developed or lower animals many are permanently fixed during life (*e.g.*, the corals, and the *Cirripedia* among *Crustacea*). In a considerable number of the lower animals, the organs of sensibility are entirely awanting. On the other hand, we find among the lower orders of plants, species which during some period of their life have the power of free movement (*e.g.*, *Bacteria*). Further, we find in many of the higher plants

movements of one part or another at certain periods of the day (*periodic* movements), and these may be brought about by external influences, as light, change of temperature, &c. To this class belong the closing of the flowers at night, and movements of the leaves. The lower the animals and plants, the greater is the resemblance between them.[1]

The following are some of the other distinctions which may be drawn between the higher animals and plants. Animals have at the anterior extremity of the body a single opening—the mouth—by which food is taken into the organism; plants obtain nourishment by their roots, which are placed at the posterior extremity of the organism. Animals have a stomach; plants have none. Among animals the green colour peculiar to plants, with the exception of fungi, is exceedingly rare.

The study or science of plants is called *Botany*.[2] This science is frequently divided into *Physiological Botany* and *Systematic Botany*. *Physiological Botany* deals with the external form and internal structure of plants, and with the functions or uses of their various parts.[3] *Systematic Botany* deals with the principles of classification of plants, or the distinctions between the various orders, and with their distribution over the surface of the earth.

[1] Among the least developed or lowest organisms it is often extremely difficult to decide whether they belong to the animal or to the vegetable kingdom.

[2] The term Botany is derived from the Greek word *botané*, herb, plant.

[3] The structural aspects in general are best kept separate as *Morphology*, with those of minute structure as *Histology*; those of function are *Physiology* proper.

PART I.

MORPHOLOGY.

ALL the parts or organs which go to make up the plant as a whole may be classified under the four following heads:—

I. *The Root.*
II. *The Ascending Axis or Stem.*
III. *The Leaves and Homologues of Leaves.*
IV. *Hairs and structures of like nature.*

A young plant just sprung from the seed is termed a seedling. In Fig. 1 we have a seedling maple, in which we can readily recognise the above-named parts. Below we see a part (*b e*) somewhat wavy in outline, and covered with delicate hair-like processes. This is the root, which is entirely underground. Just above this we find the stem (*b a*), and this bears at its upper extremity several leaves (*c c d*).

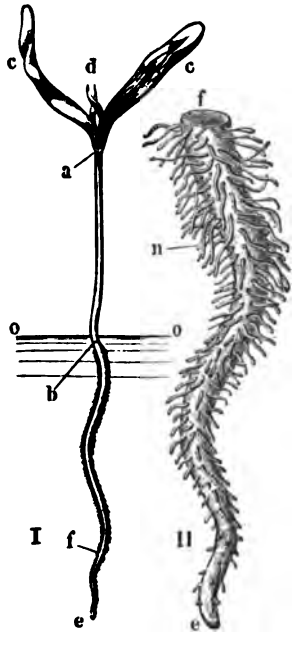


FIG. 1.

I. Maple (*Acer platanoïdes*) seedling, nat. size. II. The Root, *e f* (I.); × 6 times. *a b* Stem, *b e* Root, *c c* Seed-leaves, *d* Bud, *n* Secondary Roots, *o o* Surface of the ground.

The following are the distinguishing characteristics of these structures.

I. *Roots* are found beneath the surface of the ground; they serve to fix the plant in the earth, and grow from above downwards. They never bear leaves nor homologues of leaves; they commonly branch or divide.

II. *Stems* grow for the most part above-ground, and serve as a support for all the other aërial parts: they grow from below

upwards. They bear leaves or homologues of leaves, and are usually branched.

III. *Leaves* and homologues of leaves (leaves proper and flowers) grow on the stem or its branches. Leaves are usually flat, and are almost always of a pleasing and characteristic green colour.

IV. *Hair Structures* mostly appear simply as hairs on the surfaces of the root, stem, and leaves, or their appendages.

I.—THE ROOT.

The Root is that part of the plant which is found under the ground, and grows from above downwards. By means of it the plant is fixed, and obtains nourishment from the surrounding soil. The root has numerous branches, twigs, and filaments, by which its hold upon the soil is rendered very secure. In some few plants the root is wanting.

The nourishment absorbed by the filaments or rootlets consists chiefly of *water*, and such mineral matters as are soluble in water (salts). A very slight experiment is sufficient to show that the root absorbs nourishment in a liquid form, and so furnishes sustenance to the plant. If the soil in a flower-pot in which plants are growing is allowed to get quite parched, the plants soon shrivel up and die. On the other hand, if a plant be dug up and the roots placed in water, it will continue to live and grow for a considerable time.

The Colour of the root is usually somewhat black, grey, brown, yellow, or red, almost never distinctly green. Leaves, leaf-scales, or buds (eyes) are not found on the roots.

In many plants we find a primary root, from which secondary or branch roots are given off. The primary root (*b e*, I., Fig. 1) is that part which we find in the middle of the whole root network, and which grows straight downwards. It is the first to form when the young seedling bursts from the seed, and is simply the direct prolongation of the stem. All secondary roots spring from the primary root; from these again smaller rootlets are given off, and so on, until at last we get the numerous ramifications found among the roots of many of our most familiar plants.

Many plants possess the power of forming new roots, when, after the primary and secondary roots have been cut away, they are placed in damp mould or water. If, for instance, the root be cut away from

the seedling maple (at *b*, I., Fig. 1) and the cut end placed in water, it will form a number of new secondary roots. In Figure II. we have a young plant, the root of which has been removed; during the fort-

FIG. 3.

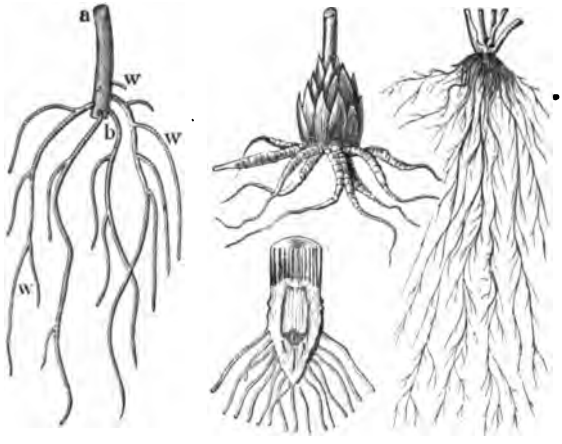


FIG. 2.

Lower end of the stem of the maple, the primary root cut away; nat. size. *a b* Stem, *w w* Roots.

FIG. 5. FIG. 4.

Fig. 3.—*Fasciculated root of* Turk's cap lily (*Lilium Martagon*); half nat. size. Fig. 4.—*Fibrous root* of a grass (*Poa annua*); nat. size. Fig. 5.—*Premorse root* of *Plantago major;* nat. size, longitudinal section.

night which it has been kept in water, it has produced the secondary roots *w w*, which now absorb nourishment. All plants which may be propagated by cutting, such as fuchsias, oleanders, currants, pelargoniums, &c., have this power of producing new roots.

In many plants the growth of the primary root soon stops, in fact shortly after the seed has sprouted. We then find only secondary roots springing from the root end of the stem (as in Turk's cap lily, Fig. 3), which form a regularly shaped bunch of strong root fibres.

EXAMPLES.—All our common trees and shrubs have primary and secondary roots. The grasses, the various species of lilies, and such exotics as palms and bananas, have only secondary or adventitious roots.

When there is no primary root, or when the primary root is very slender, we have what is termed a *fasciculated* root, which, if the secondary fibres are very fine, is further called *fibrous* (Fig. 4). Roots may become enlarged for storage purposes; note those fas-

ciculated roots of which the fibres are somewhat thickish, as those of the Turk's cap lily (Fig. 3). If the fibres are much thickened, the roots are said to be *tuberous*. If the primary root is much thicker than the branches, and ends abruptly in a blunt or rounded point, the root is said to be *premorse* (Fig. 5). The primary root, when it greatly exceeds the secondary fibres in strength and thickness, is called a *tap-root*. According to their shape, tap-roots are termed *fusiform* or *spindle-shaped*, and *napiform* or *turnip-shaped*. Fusiform or spindle-shaped roots are elongated, broad in the middle, and tapering especially to the lower end (Fig. 7). Napiform or turnip-shaped roots have the primary root almost round, or rounded and wider than high (Fig. 9).

FIG. 6.

Monotropa Hypopitys, a parasite common on the roots of the pine. It is yellow in colour; ½ nat. size. *a* Flower spike; *b c* Leaf-scales.

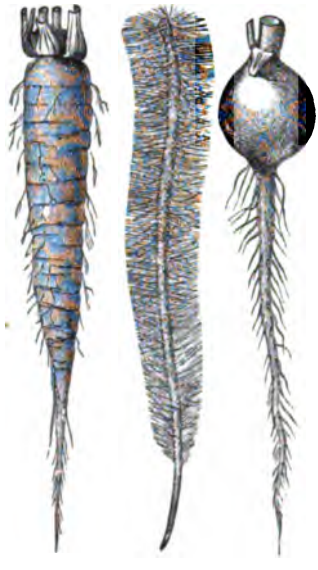


FIG. 7. FIG. 8. FIG. 9.

Fig. 7.—Spindle-shaped root of carrot (*Daucus Carota*); ½ nat. size. Fig. 8.—Aquatic root of *Hydrocharis morsus ranæ*; nat. size. Fig. 9.—Napiform root of the radish (*Raphanus sativus*); nat. size.

Examples.—The grasses (rye, wheat, barley) have *fibrous* roots. Lilies, Turk's caps, tulips have also fibrous roots, with the fibres slightly thickened; the dahlia and meadow-sweet have *tuberous* roots; *premorse*—Plantago, and devil's bit scabious, *fusiform*—carrot, parsnip; *napiform*—turnip, radish.

According as they are succulent and juicy, or hard and dry, roots are characterised as *fleshy* (beet-root, radish) or *woody* (roots of trees). Fleshy roots usually die off at the end of autumn, while many woody roots are permanent—that is to say, they remain living for two or more years, and in the beginning of spring send up new shoots and leaves.

Many plants which live on the surface of water, have roots which float about freely without penetrating the underlying mud. These are termed *aquatic* roots. They are long and slender, do not usually branch, but are covered with large numbers of delicate rootlets of equal length (*Hydrocharis*, Fig. 8).

Usually roots are buried in the soil, but in some instances they grow above-ground, and are known as *aërial roots*. One class of these roots is particularly worthy of note, namely, those of the climbing plants, such as ivy. These spring from the stem, are short and thick, and enable the plant as it grows to cling firmly to walls, trunks of trees, or other support.

Certain plants obtain nourishment neither from the earth nor from the water, but from other plants into which they send their roots. Such plants are termed *parasites* (Gr. *parasitos—para*, beside, *siteo*, to feed). Many prey upon the roots of cereals (Gerardia), others upon stems and trunks of trees (dodder, mistletoe). Many parasitic plants have no green leaves, but instead have small yellow or brownish scales (*b c*, Fig. 6); as a rule the whole plant is distinguished by this yellow or brownish colour.

Although in this climate we have few or no examples of plants of great size bearing aërial rootlets, they are very numerous in the tropics. The mangrove forests, which run along the swampy sea coasts in the Torrid Zone (in Central America and India, for example), are entirely composed of trees bearing aërial roots. The gnarled and twisted root branches rise out of the slime and mud in which they are fixed, so that the lower end of the trunk is a considerable height above the ground. From every bough and twig thread-like aërial roots are given off, which grow downwards and penetrate the ground, thus supporting the tree on all sides. The mangrove forests, with their countless aërial roots, form an impenetrable thicket, peopled with swarms of mosquitoes. The air is filled with poisonous exhalations from the swampy ground, where crabs, molluscs, and other sea creatures find a congenial abode. In India there are certain trees of the fig species (banyan, *Ficus Indica*) which likewise give off aërial roots, from which, after they have become fixed in the ground, new plants originate.

Under aërial roots we must consider those of certain peculiar tropical plants which do not grow in earth, but on the trunks and branches of trees (Fig. 10). Their roots cling fast to the crevices of the bark and the little niches formed where branches are given off, but do not penetrate the tissues of the tree like the roots of true parasites. They grow on the tree without taking any nourishment

from it. *Epiphytes* (Gr. *epi*, upon, *phyton*, a plant), or air-plants, is the name which has been given to them. They are peculiar to tropical forests. Like moss and creepers in our own country, they

FIG. 10.

Orchid, with roots attached to the trunk of a tree (*Oncidium Papilio*, an orchid bearing tubers on its roots).

frequently cover the trunks and branches of the trees so completely as to hide them from view. The epiphytes most frequently met with in the tropics are Orchids (*Oncidium*, Fig. 10, *Epidendrum*, *Odontoglossum*, in the tropical regions of America; *Comparettia* in Peru), and plants of the pine apple order (*Tillandsia*, in Tropical America).

II.—THE STEM.

In common parlance the word *stem* is used to denote that part of a plant which is visible above ground, and bears leaves either on itself or on its branches. In botany it is used in a somewhat wider sense, as the following paragraph will show.

Root and stem together form the support for all the other parts of the plant,—leaves, flowers, and hairs; taken conjointly, they, *i.e.*, the root and stem, may be conveniently termed the

axis. The root is the *descending*, the stem the *ascending* axis. Usually the root, as we have already seen, grows beneath the surface of the earth, the stem above it. This remark, however, holds good only of one class of stems, namely, *aërial* stems. In many plants the stem is wholly or in part underground, where it grows in a horizontal direction. An underground or *subterranean* stem is easily distinguished from a root by its bearing leaves, leaf-scales, and buds (the *eyes*), which are not met with on roots.

1.—Subterranean Stems.

Underground stems are of three kinds, *rhizomes, tubers,* and *bulbs.*

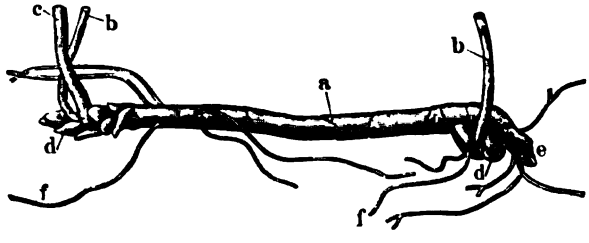


Fig. 11.

Rhizome of anemone (*Anemone nemorosa*); nat. size. *a* Scar of leaf-scale, *d* Bud, *b* Leaf-stalk, *c* Flower-stalk, *f* Roots (fibrous).

(1.) *The Rhizome* or *Rootstock.*—When a subterranean stem is cylindrical in shape it is called a *rootstock* or *rhizome* (Gr. *rhiza*, a root). An example is given in Fig. 11. At the growing point is a bud (*d*), from which shoot up in spring time a flower-bearing stalk (*c*), and leaves (*b*), which appear above the ground. In the course of the summer the axis of the bud develops into a new portion of rootstock, on which we can detect leaf-scales, or the scars of scales which have already fallen off (*a*). The rhizome here and there gives off fibrous roots (*f f*). In autumn the aërial leaves die down, while the rootstock lives on through the winter, and in spring develops the bud at its apex in the manner above described. *The rhizome is perennial.*

Examples.—The anemone (Fig. 11) and lily of the valley are examples of plants with horizontal and *creeping* subterranean stems. Many aquatic plants whose roots creep through mud have also rhizomes. The bog-bean (*Menyanthes trifoliata*) which is common in marshy spots, has a thick greenish rhizome, often over two yards in

length. The large, greenish, much-scarred rootstock of the yellow water-lily and of calamus are also familiar.

Fig. 13.

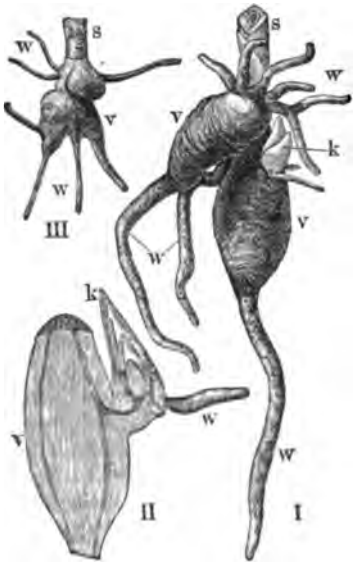


Fig. 12.

Tubers.—Fig. 12 (I., II.).—Root of orchid (*Platanthera bifolia*). I. Tuber, nat. size; II. The same, in longitudinal section, twice nat. size. Fig. 13 (III.).—Tuber of *Gymnadenia conopsea*, nat. size; *s* Stem, *v* Tubers, *k* Bud, *w* Roots.

(2.) *The Tuber.*—Another form of subterranean stem is the tuber (Fig. 12, 13). In this case one part of the stem is developed into a thick, usually fleshy mass of rounded or irregular shape, on the surface of which are found one or more buds. From these the next year's plants are produced. From the tuber numerous roots originate (*w w*).

Fig. 12, I., represents the tuber of a common orchid (*Platanthera bifolia*); Fig. 12, II., the same in longitudinal section, so as to show the bud and leaflets. Fig. 13 is the palmate tuber of another orchid (*Gymnadenia conopsea*). The potato tuber is another example of a thickened subterranean stem. The *eyes* are axillary buds.

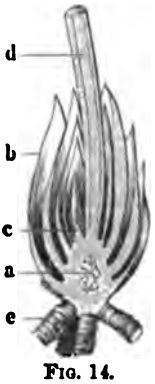


Fig. 14.

Bulb of Turk's cap lily (*Lilium Martagon*), longitudinal section. *a* Bulb core, *b* Bulb scales, *c* Bud, *d* Stem, *e* Roots; twice nat. size.

(3.) *The bulb* is a subterranean, suddenly thickened stem, enveloped in leaves, which are either short and scale-like, or thick and fleshy. The thickened stem is called the *bulb core* (*a*, Fig. 14), the surrounding leaves, if thin and dry, *bulb scales*, if thick and succulent, *bulb coatings*. The ascending part of the thickened stem (*a*, Fig. 14) bears one or more buds, from which new stems and new bulbs are formed next year. From the lower end numerous fasciculated or fibrous roots are given off (*e*, Fig. 14); these are merely adventitious; the primary root is always awanting.

Examples.—Tulip, leek, and hyacinth have tunicated bulbs; the white lily, the tiger lily, and the Turk's cap lily have scaly bulbs.

2.—Aërial Stems.

The aërial stem—the stem in the general sense of the word—is elongated and linear or cylindrical. It gives off branches, and almost always bears green leaves and flowers.

Stems may be classified according to their shape, as seen in transverse section (see Fig. 15). According to this plan we get

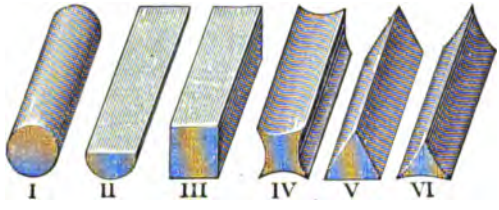


Fig. 15.

The Stem.—I. Cylindrical; II. Semi-cylindrical; III. Quadrangular; IV. Quadrilateral; V. Triangular; VI. Trilateral.

six different kinds—*cylindrical* (Fig. 15, I., circular in transverse section), *semi-cylindrical* (II., semi-circular in transverse section), *square* or *quadrangular* (III., square in transverse section), *quadrilateral* (IV., square in transverse section, but differing from the former in having the sides of the square concave), *triangular* (V., three-cornered in transverse section, the sides of the triangle being straight), and *trilateral* (VI., three-cornered in transverse section, but differing from triangular stems in having the sides of the triangle concave).

Stems may be either *soft* or *hard* and *woody*. Soft stems are always more or less succulent, and are green or greenish in colour; in which case they are said to be *herbaceous*, the plants with such stems being called *herbs*. Herbaceous stems are often hollow. A peculiar form of the hollow stem is the *culm*, of which we have a good example in the grasses (see Fig. 16). The culm is a hollow (but solid-jointed) stem, which bears leaves at each joint (*k*). The joints give the stem a knotty appearance on the exterior. In the interior we find, corresponding to each joint, a trans-

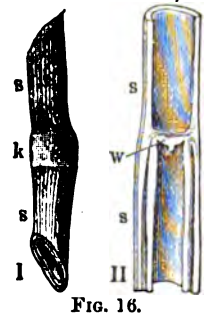


Fig. 16.

Part of the culm of a reed (*Phragmites communis*). I. Viewed from the outside; II. In longitudinal section; nat. size. *s* External wall, *k* Joint, *w* Partition.

verse partition (*w*), which can easily be seen in a longitudinal section (II.). Herbaceous stems are more common than woody stems, but the latter do not die down in autumn like the former, but live on for years—are *persistent*. They are protected externally by a thick rind, the *bark*. Plants possessed of such stems are termed *woody*. In most cases these stems are branched. If they begin to branch close to the ground the plant is a *shrub*, if they rise to a considerable height above the ground before beginning to branch, the plant is a *tree*.

FIG. 17.
Seychelles Palm (*Lodoïcea Seychellarum*).

A peculiar form of woody stem is the *caudex*, the name technically applied to the trunk of palms, *e.g.*, *Lodoïcea Seychellarum*, the Seychelles Palm (Fig. 17). These stems rise like a tall slender column, often to a great height, without giving off any branches. At the upper extremity they bear a crown of large leaves. The caudex is usually covered with scars throughout its entire length: these are the marks left by the falling away of leaves in former years.

Between woody and herbaceous stems we find many partaking of the nature of both, but which cannot properly be classed with either. In some plants, for example, the stem is woody at the lower part, but the branches and ultimate ramifications are herbaceous. The latter die down in autumn, but grow anew in spring from the more hardy and persistent parts. The term *caudex* may also be applied to herbaceous stems which do not bear leaves except at the top.

Among the different species of plants we have all varieties of height, circumference, and diameter of the stem. The stems of herbaceous plants are for the most part slender and short; yet the tropical bananas, which are neither more nor less than herbs, grow to a height equal to that of a tree. Their succulent stems have as great a circumference as an ordinary tree trunk. Among woody plants, the *trees* frequently attain to a gigantic height, an enormous circumference, and

a great age. The highest are found among the palm, the pine, and the myrtle families. The cabbage palm (*Areca oleracea*) of South America grows to a height of 150 or 160 feet; the wax palm of the Andes (*Ceroxylon andicola*) to 160 or 180. One species of pine (*Pinus Lambertiana*) in North-western America is frequently over 200 feet, as is also the araucaria (*Araucaria excelsa*) of Norfolk Island. The colossal cypress of California (*Sequoia gigantea*) attains a height of 260, the gum trees of South Australia (*Eucalyptus obliqua* and *E. pilularis*) of 280 feet; while another species (*E. amygdalina*) is said to reach the enormous height of 460 feet. The first two species, for all their great height, have a circumference of only 15 feet. We have given some examples of trees which attain great height; let us now take a few of those which attain to great circumference and correspondingly great age. Oaks have been felled in Poland which had a circumference of 46 feet, and whose age, when calculated according to the number of annual rings, must have been 710 years. In Lithuania a lime tree was felled which measured 78 feet round, and had 815 rings. A yew found in the north of Wales measured 46 feet round, and must have been 1400 years old. The famous dragon-tree of Orotava, in the island of Teneriffe (*Dracæna Draco*), was 63 feet high, 45 feet round, and was supposed to be several thousand years old. But these are all excelled by the baobab of Africa (*Adansonia digitata*). Some of those trees were found in Senegal measuring from 60 to 70 feet high and 93 feet round, while their age was calculated to be over 5000 years.

These vegetable giants may be compared with the plants which grow in close proximity to perpetual snow—Alpine and Polar vegetation. Their stems, frequently woody, are so short that they can scarcely be said to rise above the ground at all. At this low elevation they bear a crown of thick-set leaves, from the midst of which a flower-stalk is developed during the short summer.

3.—Peculiar Forms of Stem.

(1.) *Twining Stems.*—Many plants attain to a good height although their stems are slender and weak. This they do by supporting themselves on stronger plants growing in their neighbourhood. Because they thus support themselves by circling their stems around the stems or trunks of those plants, they are called *twining* plants. The twining stem may be either herbaceous or woody.

Fig. 18.
Thorn of hawthorn (*Cratægus Oxyacantha*). *s* Stem, *a* Thorn, *b b* Leaves.

Examples. — Familiar instances of twining plants are given by bindweed

and hops. In the forests of Waldern the trees are usually covered with hundreds of twiners called *lianas* (from Spanish *liar*, Fr. *lier*, Lat. *ligare*, to bind). It is these which render tropical forests so impenetrable. A more or less familiar representative of the lianas is a certain species of cane (*Calamus rotang*), an East Indian climbing palm.

(2.) *Tendrils.*—In many plants certain parts of the stems have developed into distinct organs for laying hold of anything that may offer itself as a support. These are termed *tendrils*

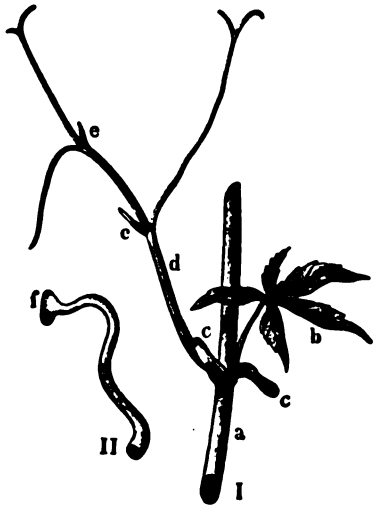


FIG. 19.

I. Tendril of wild vine (*Ampelopsis hederacea*); II. End of a tendril; *a* Stem; *b* Young leaf; *c c* Stipules; *d* Tendril; *f* End of tendril; nat. size.

FIG. 20.

Leaf-like stem of Phyllanthus. I. With flowers (*b*); II. With fruits (*f*); half nat. size.

(Fig. 19). In most cases the tendril (*d*) originates opposite a leaf (*b*), is frequently branched, and itself bears small scale-like leaves (*e*). Fig. 19, II., represents the end of a tendril which had attached itself to a crevice in a wall.

(3.) *Stolons.*—A stolon is a prostrate stem, or rather branch of a stem. At intervals it strikes root, and at this point a new plant develops—*e.g.*, the strawberry plant.

(4.) *Thorns.*—A spine or thorn is a short hardened branch terminated by a point (*a*, Fig. 18). It is covered with bark, and frequently bears leaves (*b*).

(5.) *Leafy stems.*—In some cases stems have been developed so as to have the appearance and fulfil the functions of leaves. Such are called *leaf-like* stems. In Fig. 20 we have the leafy stem of a tropical milkweed, *Phyllanthus* (from the Gr. *phyllon*, a leaf, and *anthos*, a flower, because the flower seems to grow out of a leaf). What appear to be the veins of the leaf, but are in reality branches from the primary stem, are united by masses of green leaf-like substance; they bear flowers at the end (I. *b*), which later on become the fruit (II. *f*).

III.—THE LEAVES AND HOMOLOGUES OF LEAVES.

Leaves grow on the stem or its branches. Their growth takes place mainly in two directions, namely, in length and breadth; accordingly they are of a flat shape. Stems and roots have all the three dimensions,—length, breadth, and thickness; in the language of geometry, they may be said to have *body*. They are most developed as regards length; the development of breadth and thickness is about equal. This does not mean, however, that leaves have no thickness whatsoever, only their thickness is small compared with their length and breadth. Leaf-organs include leaves proper and flowers.

A.—Leaves (Proper).

This term is also used by botanists to indicate those structures popularly called the "leaves" of plants; they are almost always green and flat. We have to distinguish, however, between *cotyledons* or *seed leaves* and true *foliage leaves.*

1.—*The Cotyledons.*

If we cut the seed of a plant in two transversely, *e.g.*, a bean (Fig. 21, I., *a b*), we find it to be composed of two thick, hardish parts, which are very important in connection with the growth of the young plant. If the bean be buried in moist soil it absorbs water; this causes the two parts (*c c*) to swell out

and burst the external coat (*f*), and the young plant contained in embryo in the seed begins to grow. Downwards it sends the root (*w*, III.), upwards the stem (*s*), which later on bears leaves (*b*, *d*) and flowers. Along with the stem, the two parts (*c c*) already developed are pushed above the surface of the ground, assume a green colour, and become two thick fleshy leaves. As these lie ready formed in the seed, they are called *seed leaves* or *cotyledons*. There are either one or two *seed leaves* in the seed, very rarely more.

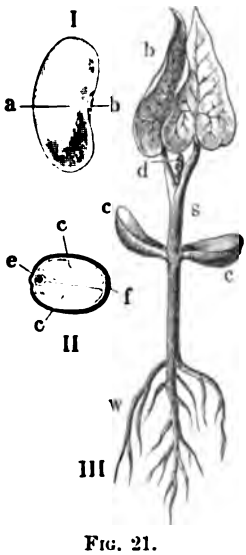


FIG. 21.

French Bean (*Phaseolus vulgaris*). I. Seed; II. The same in cross section; III. Seedling; nat. size. *f* Shell of the seed, *c c* Cotyledons, *e* Seed, *w* Root, *s* Stem, *b* Leaves, *d* Bud.

The cotyledons are formed at the expense of the parent plant, and contain nourishment for the seedling. When the seed begins to germinate, and the young root is still unable to absorb nourishment from the soil, the nutritive matter stored up in the cotyledons makes its way to the growing parts of the plant, and provides it with means for farther growth. The nutritive properties of leguminous plants (beans, lentils, peas), upon which their value as articles of food depends, are entirely owing to the store of nourishment accumulated in the cotyledons. What was fit food for the plant is fit food for us. Cooking does for man what germination does for the plant,—rendering the nutritive matter capable of utilisation by the organism.

2.—*The Foliage Leaves.*

The ordinary or true leaves are developed from leaf-buds in the following manner:—If we examine a leafy branch in summer, we find in the *axils* of the leaves,—that is to say, at every point where leaves spring from the stem,—and in the angle *between* the stem and the leaf, a *leaf-bud*. Leaf-buds form little prominences of a greenish or brownish colour, and in the early stages of growth are sometimes called "eyes" (*e.g.*, in the rose). In the course of the summer they attain their full size, and become plainly discernible when in autumn the accompanying leaf falls off, leaving a *scar* behind it (*b*, Fig. 22, I.). The surface of such a scar has the appearance shown in Fig. 22, I. The

buds (*k*) live over the winter, and give rise next spring to a new leafy twig or shoot, so that where this year we had merely a leaf, we have next year a branch bearing leaves of its own. This branch in the course of the summer develops as many buds as it has leaves. The whole of the coming shoot is contained in the bud, as we can see if we examine a longitudinal section of a bud with the lens (Fig. 22, II.). In the middle is a somewhat blunt-pointed body, the future branch or axis (*a*). On both sides, closely packed and folded together, lie the young leaves, which are already of a bright green colour (*b b*). Externally, the bud is coated with hard, dry, brown scales,—the *bud-scales* (*d*, Fig. 22, II.; *k*, Fig. 22, I.).

FIG. 22.

Elm (*Ulmus campestris*). I. Shoot, with buds; nat. size. II. Bud in longitudinal section, enlarged 3 times. *k* Buds, *b* Leaf-scar, *d d* Bud-scales, *a* Axis of branch yet in the bud.

The leaf-scales are of great importance to the bud, since they render it capable of standing the winter. Closely overlapping one another as they do, they form a sort of armour, which protects the tender internal parts from harm. Many bud-scales have a bitter taste, which prevents insects from attacking their precious contents. Many secrete a sticky, gummy, or resinous substance, and thus cement themselves together, forming an effectual protection against cold and damp. One can easily see the extent to which this secretion of resin and gum goes on by a glance at the opening buds of the horse chestnut, which are so thickly coated over with the sticky fluid that they shine when the sun's rays strike upon them, and, if touched, adhere to the fingers. If, however, all these precautions should prove unavailing, and the bud should be destroyed,—as may happen by frost, for example,—the plant does not remain throughout the summer bare and leafless. *Beneath* the bark there are yet other buds, which only develop further when by any mischance the ordinary buds are destroyed. These are termed *latent* buds.

(a.) *Parts of the Leaf.*

In a typical leaf the following parts may be distinguished. Between the stem and the blade of the leaf, there is, as it were,

a secondary stem bearing the leaf at the further end. This is the *leaf-stalk* or *petiole* (*sb*, Fig. 24, I. II.) The flat green part is the *lamina* or *blade*. Two parts of the leaf may be yet more particularly denominated, viz., the *base* of the leaf, or that part where the petiole ends and the blade begins, and the *apex*, or uttermost tip of the leaf, situated at the opposite extremity of the blade from the base. The leaf blade is penetrated by *veins* or *nerves*. In many instances the vein which traverses the blade in the long direction, *i.e.*, from base to tip, and which represents the prolongation of the petiole, is the strongest; it is called the *midrib* (*h*, Fig. 24). When the other veins likewise spring from the same point at the base of the leaf, and run parallel to one another to the tip (Fig. 25, I.) the leaf is said to be *parallel veined*. When they spring in pairs from the midrib and run towards the margin, they are simply called *veins* or *veinlets*, according to their size, and the leaf is said to be *reticulated*.

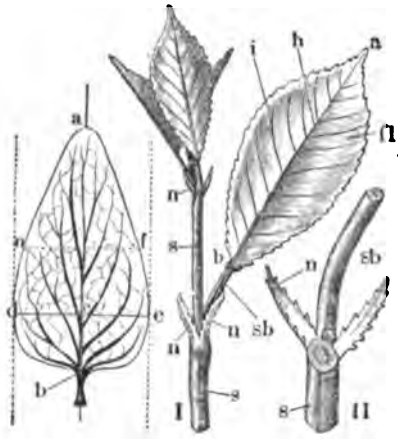


FIG. 23. FIG. 24.

Fig. 23.—Leaf of honeysuckle (*Lonicera Xylosteum*); nat. size. *b* Base, *a* Apex, *a b* Longitudinal diameter, *d e* Transverse diameter. Fig. 24.—Leaves of bird cherry (*Prunus avium*). I. End of a shoot; nat. size. II. Stipules; twice nat. size. *s* Stem, *s b* Leaf-stalk or petiole, *n* Stipules, *b* Base of the leaf, *a* Apex, *h* Midrib, *i* Veins, *k* Blade.

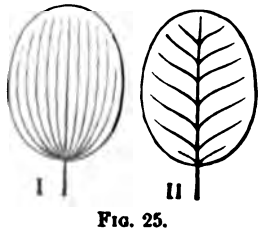


FIG. 25.

Venation.—I. Parallel. II. Reticulated.

(b.) *Shapes of Leaves.*

Leaves vary much in shape, but there are three simple forms from which the more complex are all derived. These are *orbicular* or *circular*, *elliptical*, and *ovate* (Fig. 26). In the *circle* the longitudinal and transverse diameters are equal (I., *a b* and *d e*). They bisect each other at the point *c*, the centre of

the circle. In the *ellipse* (II.) the longitudinal diameter or major axis (*a b*) is greater than the transverse diameter or minor axis (*d e*); these two likewise bisect each other at the centre of

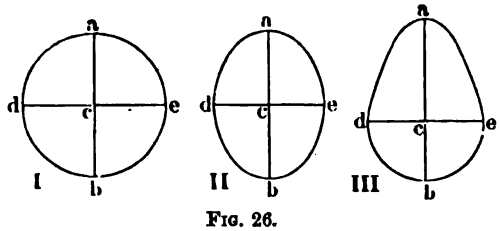


FIG. 26.

The three primary types of leaves.

I. *Circular.*	II. *Elliptical.*	III. *Ovate.*
$a\,b = d\,e$	$a\,b > d\,e$	$a\,b > d\,e$
$a\,c = b\,c$	$a\,c = b\,c$	$a\,c > b\,c$

the ellipse. In the *oval* (III.) the longitudinal diameter (*a b*) is greater than the transverse (*d e*); they intersect each other in such a manner that only *d e* is bisected at the point *c*, while *a b* is divided into two unequal parts, and *c* is not the centre of the figure, but lies in the lower half.

The three primary types of leaves may be expressed by the following formulæ:—

I. Circular or Orbicular.	II. Elliptical.	III. Ovate.
$a\,b = d\,e$	$a\,b > d\,e$	$a\,b > d\,e$
$a\,c = b\,c$	$a\,c = b\,c$	$a\,c > b\,c$

EXAMPLES.—*Circular leaves* — alder, aspen; *elliptical* — beech, cherry; *ovate*—honeysuckle (Fig. 23).

From the primary types we have the following derivative forms:—

(1.) *Reniform* or *kidney-shaped*, and *cordate* or *heart-shaped*, are formed by excision of part of the base of the blade (Fig. 27, I. III.). *Reniform* or *kidney-shaped* leaves have the base rounded on either side of the midrib. The outline of the base of the leaf is gently curved, not forming a sharp angle where it meets the lower end of the midrib. The term *kidney-shaped* or *reniform* is applied in its most restricted sense to leaves of the circular type having this form of base (I.). Leaves of corresponding shape derived from the ellipse are termed *oblong reniform* (II.), *those derived* from the ovate form, *ovate reniform* (III.).

EXAMPLES.—*Reniform* — Ground ivy; *oblong reniform*—marsh marigold; *ovate reniform*—white water-lily.

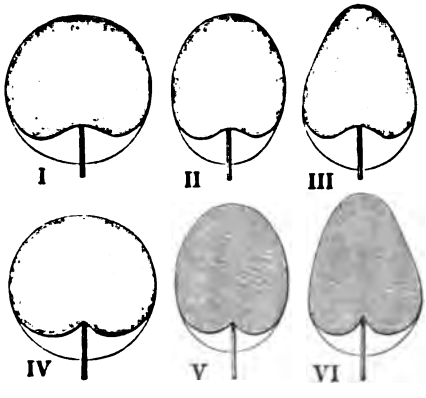


FIG. 27.

SHAPES OF LEAVES.—I. *Reniform;* II. *Oblong reniform;* III. *Ovate reniform;* IV. *Orbicular cordate;* V. *Oblong cordate;* VI. *Cordate.*

Cordate or *heart-shaped* leaves (Fig. 27, IV.-VI.) have the outline of their rounded base turned in so as to form a notch or *sinus* where it meets the midrib. In the strictest sense of the term the word *heart-shaped* is applied to ovate leaves having this peculiar form of base (VI.). Elliptical leaves with the same base are termed *oblong-cordate* (V.), orbicular, *orbicular-cordate.*

EXAMPLES.—*Cordate*—syringa, lungwort, bitter-sweet; *oblong-cordate*—yellow water-lily; *orbicular-cordate*—lime, figwort.

(2.) *By addition to the apex pointed leaves* take their rise. The addition forms an acute angle, into whose vertex the midrib is prolonged. If this takes place with the elliptical form as primary type, the leaf is *pointed elliptical* (Fig. 28, I.), if with the ovate, *pointed ovate* (Fig. 28, II.). Both shapes are alike, except that in the pointed ovate the greatest transverse diameter is found lower down than in the pointed elliptical.

Cordate and reniform leaves may also have a point of the above kind; they are then called *pointed cordate* and *pointed reniform.*

EXAMPLES.—*Pointed elliptical*—sage; *pointed cordate*—syringa.

(3.) If both the apex and the base are pointed, the leaf is said to be *lanceolate,* when formed on the primary elliptical type (Fig. 28, III.); *ovate lanceolate* when formed on the ovate type (Fig. 28, IV.). Lanceolate and ovate-lanceolate leaves look very much alike. The following are some points of distinction between them:—In lanceolate leaves the transverse diameter intersects the longitudinal diameter in the middle, in ovate lanceolate, a little below the middle of the leaf. The former have the greatest breadth at the middle, the latter a little

below the middle. In lanceolate leaves the point at the apex and the point at the base are of the same size and shape; in ovate lanceolate the point at the base is broader and less acute than that at the apex.

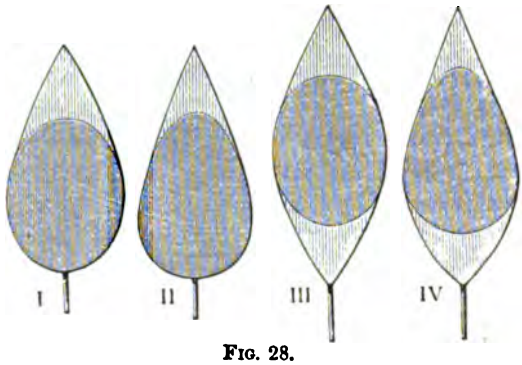


FIG. 28.

SHAPES OF LEAVES.—I. *Pointed elliptical;* II. *Pointed ovate;* III. *Lanceolate;* IV. *Ovate lanceolate.*

EXAMPLES.—*Lanceolate*—willow-herb, flax, buckthorn, oleander; *ovate lanceolate*—bugloss.

Note.—Lanceolate leaves which are very long in proportion to their breadth are called *narrow* or *linear lanceolate.*

(4.) Ovate reniform and cordate leaves are further modified to form *hastate*, or *halbert-shaped*, and *sagittate*, or *arrow-shaped*, leaves (Fig. 29). *Hastate* leaves are *ovate reniform* leaves with a pointed apex, and two long pointed projections at the base instead of the usual rounded lobes. The same applies to *sagittate* leaves, only the primary type in their case is cordate (Fig. 29, II.). The principal distinctions between the two shapes of leaf are as follows:—The pointed lobes at the base of hastate leaves form a curve at their junction with each other and the midrib; those of sagittate leaves form an angle. The lobes at the base of hastate leaves point outwards from the leaf-stalk; those of sagittate leaves droop somewhat downwards

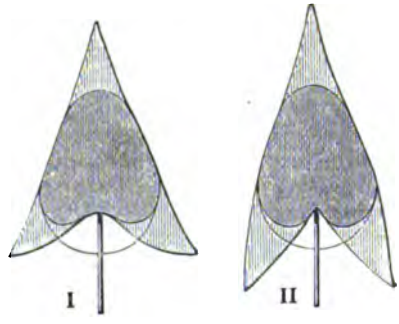


FIG. 29.

SHAPES OF LEAVES.—I. *Hastate;* II. *Sagittate.*

EXAMPLES.—*Sagittate*—Arum, sagittaria or arrow-head; *hastate*—sheep's sorrel.

Note.—Sagittate leaves whose lobes, instead of being sharply pointed, are rounded, are called *cordate sagittate* (bindweed).

(5.) Many leaves not only have an incision at the base, but a series of incisions all along their edges (Fig. 30). These are arranged as it were in pairs, passing inwards from the margin on either side towards the midrib. When the notch or *sinus*, formed by the junction of two incisions, is acute, the leaf is said to be *cleft* (I.); when a rounded curve is formed the leaf is said to be *lobed*. The leaf, Fig. 30, I., is *cleft orbicular*, because its primary type is the circle; Fig. 30, II., is *lobed elliptical*, because its primary type is the ellipse.

EXAMPLES.—*Cleft orbicular*—lady's mantle; *lobed elliptical*—oak.

In all leaves hitherto described the green blade forms an undivided whole; they are called simple leaves.

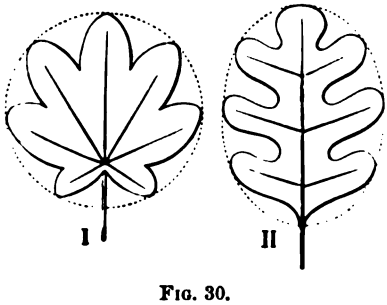


FIG. 30.

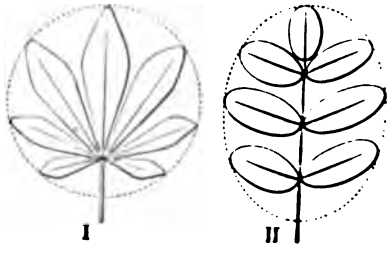


FIG. 31.

SHAPES OF LEAVES.—I. *Cleft;* II. *Lobed.* I. *Palmate;* II. *Pinnate.*

(6.) When the incisions penetrate so deeply as to reach the point where the veins spring from the midrib, the leaf becomes cut up into distinct parts or segments, called *leaflets*. All leaves composed of several segments or leaflets are called *compound*. There are two kinds of compound leaves, *palmate* and *pinnate*. In *palmate* leaves (Fig. 31, I., corresponding to Fig. 30, I.) the leaflets all originate from one point at the base of the leaf; in *pinnate* leaves (Fig. 31, II., corresponding to Fig. 30, II.) the leaflets are arranged along the midrib in *pairs*.

EXAMPLES.—*Palmate*—horse chestnut, lupin; *pinnate*—locust tree, vetch.

(7.) *Pinnate* leaves are of several kinds (Fig. 32).

(*a.*) The *trifoliolate* leaf is composed of a *pair of leaflets* and an *odd terminal one;* all three leaflets spring from one point.

The trifoliolate leaf forms the link between the pinnate and palmate forms. It may even be regarded as a palmate leaf, having only three leaflets.

EXAMPLES. — *Trifoliolate*—white and red clover, laburnum, sorrel, bogbean.

(*b.*) *Impari-pinnate* leaves are composed of a certain number of pairs of leaflets with an odd leaflet at the end, *i.e.*, they have always an *odd* number of leaflets (5, 7, 9, 11, 13).

EXAMPLES.—*Impari-pinnate*—locust tree, rose.

(*c.*) *Pari-pinnate,* or *abruptly pinnate,* leaves are similar to the *impari-pinnate,* but the odd leaflet is awanting (Fig. 32, III.), *i.e.*, they have always an *even* number of leaflets (4, 6, 8, 10, 12).

EXAMPLES.—*Pari-pinnate*—wood vetch (*orobus*).

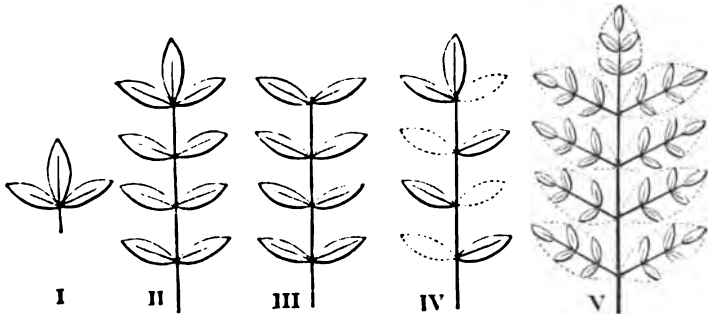


FIG. 32.

COMPOUND LEAVES.—I. *Trifoliolate;* II. *Impari-pinnate;* III. *Pari-pinnate;* IV. *Alternately pinnate;* V. *Bipinnate.*

(*d.*) *Alternately pinnate* leaves (Fig. 32, IV.) are *impari-pinnate* leaves, of which only the alternate leaflets of each pair are developed. The number of leaflets may be either odd or even (3, 4, 5, 6, 7).

EXAMPLES.—*Alternately pinnate*—the potato. *Alternately pinnate* leaves may also be modifications of the pari-pinnate form, in which case there is no leaflet at the end.

(*e.*) *Bipinnate* or *twice-pinnate* leaves (Fig. 32, V.) have compound leaflets where the ordinary pinnate leaf would have simple leaflets.

EXAMPLES.—*Bipinnate*—water hemlock; many ferns.

Note.—A distinction is to be made between *impari-bipinnate* (Fig. 32, V.) and *pari-bipinnate* leaves. Also the simple leaflets of *bipinnate* leaves may be further broken up into compound leaflets when the leaf is said to be *tripinnate* or *thrice-pinnate.*

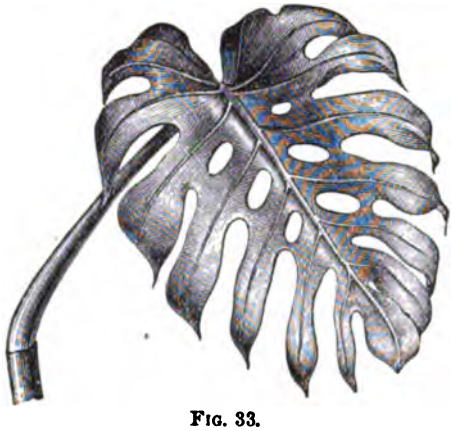


FIG. 33.
Perforated leaf of *Monstera deliciosa*; $\frac{1}{10}$ natural size.

The gradual transition of leaves from simple to compound is well exemplified in the case of the *Philodendron* and *Tornelia* or *Monstera* species. These are climbing plants of Tropical America which grow in mud, or cling to surrounding trees by means of aërial roots. In the early stages of growth the leaves of those plants are perforated by somewhat long-shaped openings, which by-and-by unite with the margin and form deep indentations. Behind these we frequently find another row of openings, which in their turn unite with the indentations of the margin, and the formerly cordate leaf becomes almost impari-pinnate.

(8.) *Peculiar forms of Leaves.*—We have now obtained some notion of the principal shapes to be met with among leaves. There yet remain, however, several important forms which we must consider before going further.

FIG. 34.

FIG. 35.

Fig. 34.—*Palmately decompound* leaf of the buttercup (*Ranunculus acris*). Fig. 35.—*Needles* of the pine (*Pinus sylvestris*); nat. size.

(*a.*) *Linear* leaves are long, narrow, and flat, not unlike a foot-rule. If in addition to this they are stiff, they are said to be sword-shaped.

EXAMPLES. — *Linear* — rye, oats, barley, wheat; *sword-shaped* — iris, calamus, gladiolus.

(*b.*) *Acicular* leaves or *needles* are strong, stiff, narrow, and pointed.

EXAMPLES.—*Needles* are characteristic of the pines (Fig. 35), and occur also among many of the myrtles.

(*c.*) *Decompound, digitately* or *palmately decompound* leaves (Fig. 34) are midway between cleft and palmate, or lobed and pinnate. The indentations of their margins are so deep that they *almost* reach the midrib. A small strip of the green blade is, however, left on either side of this and of the other veins.

EXAMPLES of leaves *between cleft and palmate* are buttercup (Fig. 34), *between lobed and pinnate*, cummin, fool's parsley, carrot, and other Umbelliferæ.

(*d.*) Many plants bear *leaves of different shapes.* On many the *root-leaves*, or leaves growing on the lower part of the stem immediately above the root, differ from those which grow higher up. More rarely we find two quite different sorts of leaves on the same branch (Fig. 36).

EXAMPLES.—Shepherd's purse is a plant whose root-leaves differ from the ordinary leaves. The gum trees (*Eucalyptus*) of Australia, already referred to, bear, in the early stages of growth, two different sorts of leaves on the same branch. Water plants, some of whose leaves are above water, some below, have often two different sets of leaves, one specialised for floating on the surface, the other adapted for remaining always submerged. In the water buttercup (Fig. 36), the floating leaves are simply lobed (*b*); those which are perpetually submerged are much divided, and almost thread-like.

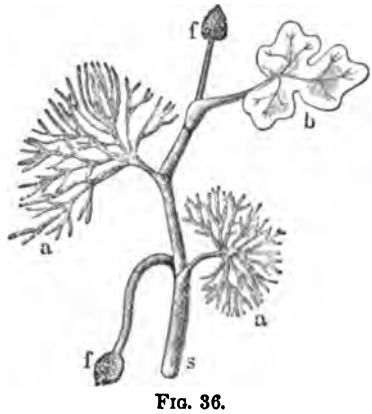


FIG. 36.

Water buttercup (*Ranunculus aquatilis*); nat. size. *s* Stem; *f* Fruit; *a* Submerged; *b* Floating leaves.

(9.) *The Margin.*—Cleft and lobed leaves are the result of marginal indentations so deep that the shape of the leaf is essentially altered thereby. It very seldom happens that the margin is quite smooth and entire; usually it is toothed or notched, so that, although essentially changed in shape, the leaf yet assumes a certain definite and characteristic appearance. The principal forms of marginal outline are the following (Fig. 37):—

(*a.*) *Serrate.*—The margin is said to be *serrate* when it has small sharp teeth, like those of a saw, which form an acute angle with one another where they meet. (*b.*) *Doubly serrate* is the name

applied to a serrate margin where we find a large and a small tooth alternately. (*c.*) A *runcinate* leaf is one which has large irregularly shaped teeth, usually directed downwards, each tooth frequently having its margin broken by smaller serrations. (*d.*) The margin is said to be *dentate* or *toothed* (III.) when the sharp-pointed teeth form an obtuse angle with one another where they meet, or where we have a flowing curve between the points. (*e.*) A leaf is said to be *spinous* when the teeth end in strong, sharp, thorny prolongations. (*f.*) *Crenate* or *scalloped* (IV.) leaves are like those with a serrate margin, only here the teeth are rounded instead of pointed.

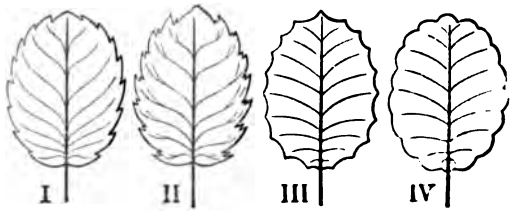


FIG. 37.

The Margin.—I. Serrate; II. Doubly serrate; III. Dentate; IV. Crenate.

EXAMPLES.—Margin *entire*—iris, locust, pea, laburnum; *serrate*—strawberry, rose, apple; *doubly serrate*—birch, briar, elm, alder; *runcinate*—dandelion; *dentate*—nightshade, hawkweed; *spinous*—holly, thistle; *crenate*—ground ivy, garlic-mustard.

Leaves may be either thin and flexible, or thick and stiff (leathery). The former, in our climate, die down in autumn, and their place is taken in spring by a fresh set. The thicker sort are frequently able to resist the cold of winter, and because their leaves do not fall off regularly like those of their more delicate neighbours, plants possessing them are called evergreens. Indigenous trees bearing such leaves are holly, laurel, box, pines, and firs.

The *size* of leaves in the Temperate Zones is not very remarkable. The largest we have do not exceed 18 or 20 inches in length. In warm countries, however, leaves sometimes attain a prodigious size. The largest leaves (pinnate) are to be found among the palms, those of the cocoa palm measuring frequently 10 or 12 feet, while the leaves of the jagua palm of the Orinoco reach a length of over 15 feet. These are equalled by the elongated *simple* leaves of the banana. Many of the tropical arums have likewise gigantic leaves; those of *Caladium* are *cordate sagittate*, and attain a length of 6 feet.

3.—*Kinds of Leaves.*

We have already explained that stem and root together are to be regarded as the *axis of the plant*. Structures of the nature

of root or stem are *axial organs;* leaf and hair structures are the *appendages of the axis.* Leaf structures include the *seed-leaves,* already described, *flowers,* whose description will follow later on, and *foliage leaves* proper.

The typical fully developed leaf consists of three parts, the *blade,* the *petiole,* and the *base of the petiole.* The *blade* and the *petiole* have already been described in a general way; the *base of the petiole* is that part of the leaf-stalk which lies next the stem, usually in some measure embracing it. It is frequently membranous and grooved on the upper side (Figs. 34, 36, *b*).

Sometimes all three parts of the leaf attain full development; sometimes one, or even two, may be suppressed.

1. When the base of the petiole only is fully developed, the petiole and blade being wanting, we get a *leaf-scale.* Such scales are not unfrequently met with on underground parts of the stem, and are sometimes called *subterranean leaves* or *under-leaves.*

EXAMPLES of these are found in the external scales of various bulbs, *e.g.*, onion, crocus, fritillary, Turk's cap lily (Fig. 3, Fig. 14); also in the leaf-scales of the anemone (Fig. 11) and the bud-scales of tubers (potato, wild hyacinth, Fig. 12, *k*).

Leaf-scales are not so frequently met with on that part of the stem which is above ground, nor are those which we have termed *under-leaves,* but they do occur sometimes, *e.g.*, in *Monotropa Hypopitys* (Fig. 6). We must, however, reckon as "under-leaves" the scales which envelop leaf-buds (Fig. 22).

2. When the *base of the petiole* and the *blade* are well developed, and the petiole is awanting, or when the *blade only* attains perfection, petiole and base being absent, we get what is called a *sessile* leaf.

In many sessile leaves the blade develops so as entirely to surround the stem, when the latter looks as if it had been pushed through the leaf; the leaf is then termed *perfoliate* (Fig. 40). When the blades of two opposite sessile leaves grow together by union of their bases, so as to have the appearance of a single leaf with a stem passing through it, the leaf is said to be *connate* (Fig. 38).

EXAMPLES.—*Sessile*—flax, henbane, woodruff (Fig. 55), garden poppy; *perfoliate*—wax-flower (*Cerinthe major*), round-leaved hare's ear (*Bupleurum rotundifolium*, Fig. 40); *connate*—lesser dead-nettle, garden honeysuckle (Fig. 38).

3. When *petiole* and *blade*, or *petiole* with its expanded *base* and *blade*, are all fully developed, the leaf is said to be *petiolate*.

Fig. 38.

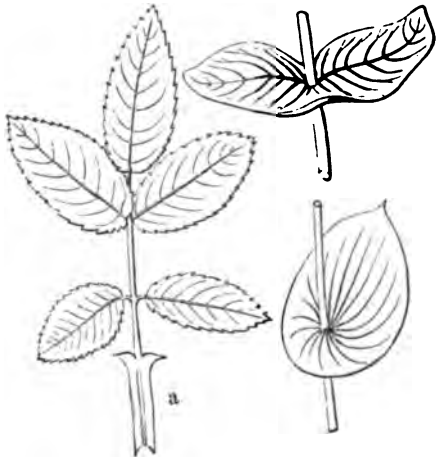


Fig. 39. Fig. 40.

Fig. 38.—Connate leaves of honeysuckle (*Lonicera Caprifolium*); nat. size. Fig. 39.—Imparipinnate leaf of rose (*Rosa centifolio*), with adnate stipules at base of petiole (*a*); half nat. size. Fig. 40.—Perfoliate leaf of hare's ear (*Bupleurum rotundifolium*); nat. size.

The petiole is in most cases stem-like (Fig. 15). It may be cylindrical, semi-cylindrical, &c. In many leaves the blade consists merely of a narrow strip running along either side of the petiole, in which case the leaf is said to be *winged*. In others the base of the petiole is expanded so as to form a pair of small leaf-like appendages or *stipules*, when the leaf is said to be *stipulate* (*a*, Fig. 39). Union of the lobes of the blade above the petiole gives rise to the *peltate* or *shield-shaped* leaf (Fig. 41). The petiole in such leaves is not united to the blade at the base of the latter, but in the centre of the under side, the outspread blade thus looking like a disc or plate supported on a slender stalk.

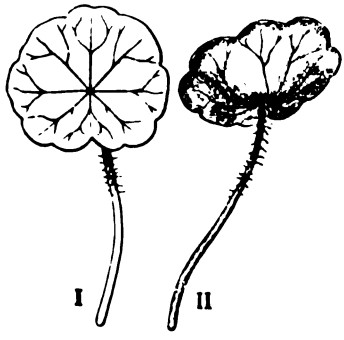


Fig. 41.

Marsh penny-wort (*Hydrocotyle vulgaris*), *peltate leaf*; nat. size. I. Viewed from above. II. From the side.

Examples. — *Petiolated leaves:* cherry, oak, birch, elm; winged—citron, mullein; *stipulate*—rose (Fig. 39); *shield-shaped* — penny-wort (Fig. 41). The base of the petiole is very strongly marked in buttercup (Fig. 34, petiolate leaf), and among the grasses (Fig. 44, sessile leaves).

Stipules.—The stipules (*n*, Fig. 42) are lateral appendages, at the base of the petiole. They may represent the free edges of the expanded base of the leaf-stalk near its point of origin from the stem. They are found on

many plants, but frequently fall off very early (*e.g.*, in many foliage plants), and by the time the foliage leaves are fully developed have entirely disappeared. They mostly appear in pairs, occasionally singly. Their form is very diverse. Just as in leaves, so also in stipules, we have all manner of modifications of the outline. Frequently they attain a considerable size, *e.g.*, in the pansy (*n*, Fig. 42), where the pinnately cleft stipules are almost as large as the ordinary foliage leaf (*b*). Sometimes they take the shape of thorns, as in gooseberry (*n*, Fig. 43). The *ligule* of grasses may also be classed among stipules (Fig. 44, *h*). The linear leaves of grasses have no petiole, but instead, a large sheath (*s*), which embraces the stem. At the junction of this sheath with the blade we find a small transparent, colourless scale, the *ligule* (*h*).

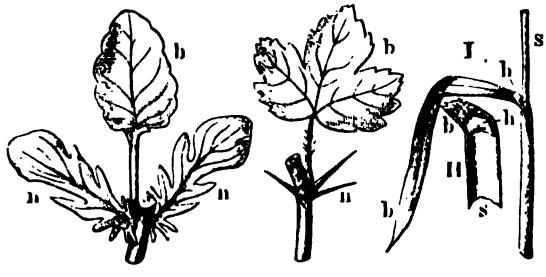


FIG. 42. FIG. 43. FIG. 44.

Fig. 42.—Pinnately cleft stipules of pansy (*Viola tricolor*).
Fig. 43.—Spinous stipules of gooseberry (*Ribes Grossularia*).
Fig. 44.—I. II. Ligule of a grass (*Poa annua*) ; *s* Base of petiole ; *h* Stipule or Ligule ; *b* Foliage leaf, nat. size. Fig. 44, II., twice nat. size.

Upper or Floral Leaves.—According to the position which leaves occupy on the stem, they are termed *under*, *middle*, and *upper* or *floral leaves*. *Under-leaves* are those before described, which grow on the underground parts of the stem, or form bud-scales ; *middle leaves* include all those on the part of the stem which is above-ground, with the exception of those in the immediate neighbourhood of the flower, which are called *upper* or *floral leaves*. Floral leaves may form either a *spathe* or a *bract*. They serve to cover and protect the flower from injury while it is yet in the bud. In many cases these leaves have reached a considerable size, while the flower bud is still very small. Some flowers have neither *spathe* nor *bract*.

(*a.*) *Bracts.*—Bracts cover *single flowers* while yet in the bud (Figs. 45 and 61). They arise from the stem at the same point as the flower-stalk, and are usually situated below it. They are small as a rule, and may be linear, lanceolate, cordate, or ovate in shape. Occasionally they are compound (deeply cleft in the lousewort (*Pedicularis*), and they frequently assume bright colours, *e.g.*, violet in the purple cow-wheat).

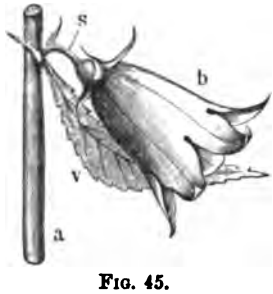


FIG. 45.

Bract (*v*) of the flower (*b*) of a bell (*Campanula Trachelium*). *s* Flower-stalk; *a* Stem, nat. size.

(*b.*) *Spathes.*—A spathe is a floral leaf which is attached to a cluster of flowers, not merely a single blossom. It grows on the common foot-stalk or peduncle. In Fig. 47 we have the spathe (*v*) on the *peduncle* (*s*) of the flower of the lime. The spathe is in this case of a yellowish green

FIG. 46.

Flower-sheath of the marsh calla (*Calla palustris*) with the young fruit; nat. size.

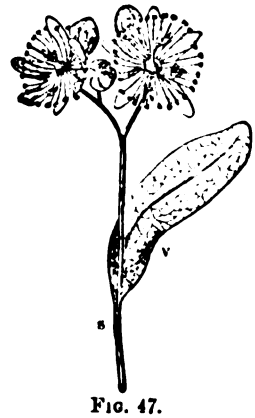


FIG. 47.

Spathe (*v*) of the lime (*Tilia europæa*). *s* Common flower-stalk; nat. size.

colour, somewhat leathery in texture, traversed by a network of small veins, and obtusely lanceolate in shape. In many cases

the spathe is very large, stiff, and not green in colour. It then encloses the flower cluster in the bud, and is called the *sheath.*

EXAMPLES. — The palms have a green flower-sheath, the much cultivated calla (*Richardia Africana*) a white one. Fig. 46 shows the white sheath of the common marsh calla; in the arum the sheath entirely surrounds the flower cluster, and is golden green in colour.

When there are *several* bracts beneath a cluster of flowers they form what is called *involucre.* The *involucre* bears the most intimate relationship to the flower, and shall therefore be treated of with it. (Under this term is included the circle of bracts of the Compositæ, and the involucre and bractlets of Umbelliferæ.) In certain plants the bracts assume the form of ordinary leaves, *e.g.*, wood anemone. Here we find three large, green, trifid, much indented leaves, from the midst of which rises the flower-stalk, with no middle leaves, but floral leaves or bracts only.

4.—*Leaves modified to fulfil Special Functions.*

It has already been said that stems are frequently modified so as to form organs of prehension, or *tendrils;* leaves may be modified to serve the same purpose. We have thus *stem tendrils* and *leaf tendrils.* A leaf tendril is simply the midrib of a leaf which has lost all traces of blade; it is capable of twining around the stems of other plants. In Fig. 48 we have the leaf tendril of the pea. The leaf in this case is impari-pinnate: the first and second pairs (1, 2) are normal, the third, fourth, and fifth (3, 4, 5), and the odd leaflet, have been modified to form tendrils. Both stem and leaf tendrils have the same function to fulfil during the life of the plant, viz., that of prehension. Looked at merely with regard to their functions, they are absolutely alike, but as parts of the vegetable organism they are essentially different; the former are homologues of the stem, the latter of the leaf.

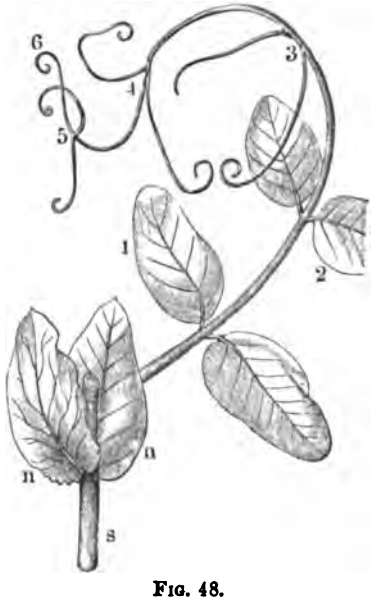


FIG. 48.
Leaf tendrils of the pea (*Pisum sativum*).
s Stem; *n* Stipules; half nat. size.

In many plants we find peculiar developments of the petiole, most intimately connected with the habits of the plant. The surface of many of the rivers of Tropical America (Surinam, the Antilles) is covered by vast numbers of specimens of a common water-plant named Pontederia. The stem of this plant grows in a horizontal direction close under the surface of the water, bearing at intervals a number of leaves and a thick tuft of aquatic roots (Fig. 8). The leaves (Fig. 50) are bright green, glossy, smooth, and of a somewhat circular shape. Externally, the petiole is swollen out balloon-wise towards the middle, internally it is perforated like a sponge: the whole forms a bladder filled with air, which supports the plant on the surface of the water. A more familiar example of the same structure is given by our own water-chestnut (*Trapa natans*).

In other plants we find that the blade of the leaf is capable of moving on the petiole. In such cases we find a cushion-like prominence, often covered with hairs, at the upper end. In Fig. 49 we have an example of such a leaf in the three-lobed wood-sorrel. During the day the three leaflets are outspread (Fig. 49, I.), at night, or when the air becomes cool, they hang down towards the petiole (Fig. 49). Noteworthy also in this respect are the movements of *Hedysarum gyrans*. Like sorrel, *Hedysarum* has three leaflets, one large and two small. In warm weather the small leaflets keep up a perpetual swaying movement, like the swinging of the pendulum of a clock.

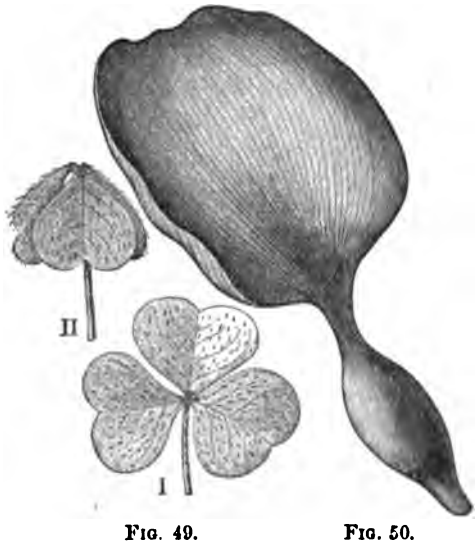


FIG. 49. FIG. 50.

Fig. 49.—Leaf of wood-sorrel (*Oxalis Acetosella*), I. during the day; II. during the night; nat. size.
Fig. 50.—Leaf of Pontederia (*Pontederia crassipes*) with bladder-like petiole; nat. size.

Very remarkable are the leaves of a certain section of plants, which have been called *insect-eating* or *insectivorous plants*. These do not, like other plants, obtain nourishment by means of their roots, but by their leaves, in the manner presently to be described. On the surfaces of their leaves provision is made for catching insects, which, once caught, are held fast until they die of hunger and exhaustion. Thereafter a viscid fluid, having digestive properties, begins to ooze out from certain glands, which by-and-by covers the dead insect, and from its body all the nutritive material it contains. This process over the

fluid is reabsorbed by the leaf along with the animal matter it has extracted, the latter being then utilised for the nourishment of the tissues of the organism. Many and varied are the contrivances for catching insects which these plants exhibit. In the Venus' fly-trap (*Dionœa muscipula*) of America, the midrib forms a sort of hinge, on which the two halves of the leaf fold together, while the bristles which fringe the edges become firmly interlocked. The insect is thus imprisoned in a living tomb, which does not open until all movement on his part has ceased—in other words, until he is dead. In our own sundew (*Drosera*) the whole surface of the leaf is covered with long, straight, glandular hairs. If an insect alights upon this plant, the hairs immediately begin to bend over, so as to enclose it and press it down towards the surface, while the viscid secretion exudes copiously from the red glands, causing speedy death to the prisoner.

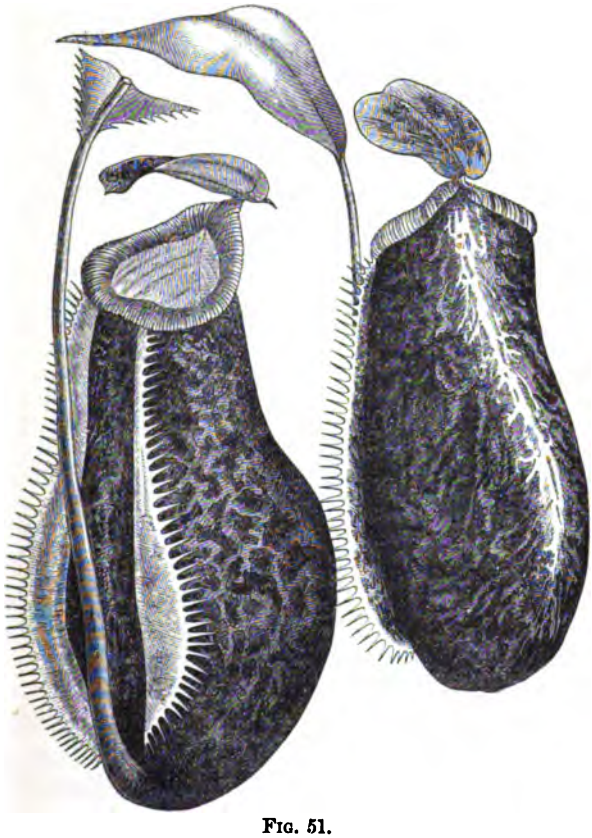


FIG. 51.

Two pitchers of *Nepenthes*. To the right *N. Outramiana*; to the left *N. robusta*; three-fourths nat. size.

Most wonderful of all, however, are the pitcher plants of the tropics (*Nepenthes*, Fig. 51). In these the midrib of the leaf is prolonged beyond the blade, and bears at its apex a daintily shaped pitcher. The pitcher is somewhat pear-shaped, and has a lid, which secretes a sweetish viscid fluid, while the walls of the pitcher also secrete a large quantity of fluid. When the lid has opened, the pitcher is visited by numerous insects, attracted by its tempting contents. Many of these unwary visitants venture down into the fluid, where they are speedily caught and suffocated. They are afterwards digested and utilised by the plant as food.

5.—*Phyllotaxis, or Arrangement of Leaves.*

Phyllotaxis is the technical term used to designate the distribution of leaves on a branch or stem. If the leaves are arranged singly on the stem so as to look at first sight as if quite irregular, the arrangement is said to be *alternate* (Fig. 53). If the leaves

FIG. 52. FIG. 53.

Fig. 52.—Decussate leaf arrangement of the syringa (*Syringa vulgaris*). Fig. 53.—Alternate leaf arrangement of the bird cherry (*Prunus avium*); ½ nat. size.

spring from the stem at the same height, and one on either side, so as to form a pair, the arrangement is said to be *opposite*. Again, if pairs of opposite leaves are so arranged that the long diameter of the first pair runs from right to left, of the second pair in a direction at right angles to that of the first, of the third again from right to left, the arrangement is said to be

decussate (Fig. 52). When several leaves stand circularly round the stem at the same height, the arrangement is said to be *whorled* or *verticillate* (Fig. 55).

Note.—A branch with opposite leaf arrangement may be distinguished from a pinnate leaf by the fact that buds are found in the axils of its leaves.

EXAMPLES.—*Alternate*—apple, cherry (Fig. 53) oak; *opposite*—snowberry (Fig. 54; in snowberry the leaf arrangement on young shoots is *decussate*), ash; *decussate*—syringa (Fig. 52), dead-nettle, chickweed; *whorled*—woodruff (Fig. 55).

FIG. 54. FIG. 55.

Fig. 54.—Opposite leaves of snowberry (*Symphoricarpus racemosus*); half nat. size. Fig. 55.—Whorls of woodruff (*Asperula odorata*); nat. size.

Laws of Phyllotaxis.—Even in cases where the distribution of leaves seems most irregular, a certain system—the result of definite laws—still prevails, although frequently very difficult to make out. Suppose that, while slowly rotating a stem about its own axis, we draw on its surface a line beginning at the base of the foot-stalk of the first leaf, thereafter prolonging it so as to pass through that of the second, third, and so on, the result will be a spiral or helix which touches the point of origin of all leaves on the stem.[1] If, starting again from the first leaf, we endeavour to find the one *directly over it*, we shall find that the spiral, before touching it, has made a certain number of turns (1, 2, 3, 5, &c.), and in so doing has passed through the points of attachment of a certain number of leaves (3, 5, 8, 13, &c.)

[1] To illustrate this spiral arrangement, take a cylinder of given length and cut out in paper a right angled triangle, of which one of the sides enclosing the right angle shall be equal in length to the cylinder. By this side fasten the triangle to the latter, parallel to its long axis, and then wrap it round. The hypotenuse will then form on the surface of the cylinder a spiral, the turns of which are less steep and more numerous the greater the length of the hypotenuse (Fig. 56). When the triangle is unrolled, the unattached base will also form a spiral with an equal number of turns. These will be all in one plane, while the turns of the spirals of the hypotenuse will not.

The two together may be expressed by a fraction, the number of turns being placed as numerator, the number of leaves as denominator, *e.g.*, $\frac{2}{5}$. This fraction expresses the $\frac{2}{5}$ arrangement. That is to say, in a plant whose leaf arrangement is expressed by the fraction $\frac{2}{5}$, two turns of the spiral will touch five leaves, and the sixth leaf will be the one directly over the first. The leaves 1 to 5 form what is called a *leaf-cycle*. In Fig. 56, II. we have a diagrammatic representation of the $\frac{2}{5}$ leaf arrangement. At I. begin the two turns of the spiral which pass through leaves 1, 2, 3, 4, 5; leaf 6 stands directly over 1, and forms the commencement of the second cycle, II. Fig. 56, I. is a diagram of the $\frac{1}{3}$ arrangement, that is to say, of a leaf arrangement in which the first, fourth, seventh, tenth, &c., leaves are directly over one another, each removed from the other by a single turn of the spiral (I., II., III., IV., &c.). Each turn passes through three leaves—three compose the cycle.

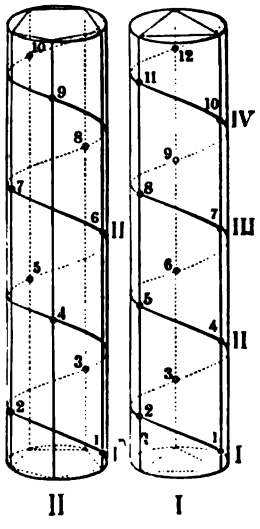


FIG. 56.

Leaf arrangement.
I. $\frac{1}{3}$ arrangement.
II. $\frac{2}{5}$ arrangement.

In young growing shoots where the leaves stand far apart, the study of the leaf arrangement is rendered still more complicated by the stems twisting. It is much more easy when we come to stems which are short in proportion to their thickness, and which thus have their leaves arranged in a rosette (*e.g.*, *Plantago major*). In this plant the leaves of later growth are smaller than the older ones. In order, therefore, to determine the arrangement we connect by a curve the first leaf with the next of the same size, and continue this process in gradually lessening circles, until we reach a point where we come to a leaf on the same radius as the one we started with. We then count the number of turns necessary to reach this point, and the number of leaves touched thereby, and then, as before, place the former as numerator and the latter as denominator of our fraction. Fig. 57, II. shows the $\frac{3}{8}$ arrangement of the rosette of Plantago thus worked out. Fig. 57, I. the $\frac{2}{5}$ arrangement of a similar rosette. In the $\frac{2}{5}$ arrangement leaves 1, 6, 11, &c. lie over one another; from 1-6, from 6-11, &c., two spirals are traversed each time. In the $\frac{3}{8}$ arrangement 1, 9, 17, &c. lie over one another; from 1-9, from 9-17, three spirals are always traversed.

Not only do we have $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$ arrangements, but many others, which need not be entered into here. The most usual are such as are formed by the addition of the numerators and denominators of the fractions $\frac{1}{2}$ and $\frac{1}{3}$, or $\frac{1}{2}$ and $\frac{2}{3}$, thus: *first series*—$\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, $\frac{21}{55}$, &c.; *second series*—$\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{5}{8}$, $\frac{8}{13}$, $\frac{13}{21}$, $\frac{21}{34}$, $\frac{34}{55}$, &c.

The $\frac{1}{2}$ arrangement is termed *distichous* or *two-ranked*; it is characteristic of many lilies, the aloe, agapanthus, and gladiolus. The $\frac{2}{5}$ arrangement is the most common; examples of it occur in the elm, cherry, oak, &c. The arrangements of the scales on the cones of *coniferæ* (firs, pines) is very complicated, and their spirals very numerous.

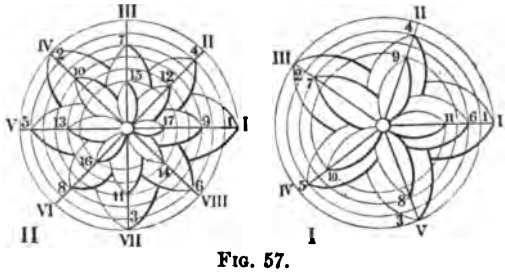


FIG. 57.

Rosettes of leaves. I. $\frac{2}{5}$ arrangement. II. $\frac{1}{2}$ arrangement.

B.—THE FLOWER.

All those leaf-like organs which are in any way connected with the formation of the fruit are included under the general name of *flowers*. This holds good in botanical as well as popular language. As all the parts which go to form the flower are arranged in close proximity to one another, and separated from surrounding parts of the plant by a special stem (*the flower-stalk*), the flower, as such, is easily recognised. Although in general appearance flowers are very unlike ordinary foliage leaves, yet all their parts partake of the nature of leaves.

Looked at from the outside, we see that a flower is composed of *several* leaves, of which there may be an *outer whorl*, coloured *green* (*k*, Fig. 58). Within this whorl we find a second group, usually much larger than the first, and easily distinguished by their brilliant colour. These are frequently so arranged as to form a covering for the protection of the more essential organs which they

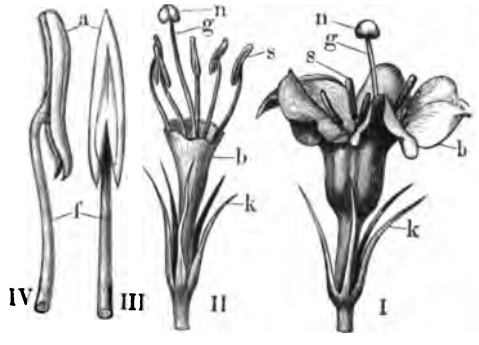


FIG. 58.

Flower of *Weigelia japonica*. I. Entire flower; II. The same with upper part of corolla cut away; III. Stamen (front view); IV. Stamen viewed from side; *k* Calyx, *b* Corolla, *s* Stamen, *a* Anther, *f* Filaments, *g* Style, *n* Stigma. I. II. nat. size; III. IV. magnified 3 times.

enclose (*b*, Fig. 58). These two kinds of leaves are called the *floral envelopes*. The outermost green-coloured envelope is the *calyx* (*k*); the inner brightly coloured one is the *corolla*. The leaves of the calyx are the *sepals*, those of the corolla the *petals*.

EXAMPLES.—*White corolla*—lily, white dead-nettle, mock orange blossom, chickweed, cherry blossom, apple blossom; *rose pink*—Weigelia, red foxglove, rose; *deep red*—poppy, pheasant's eye; *yellow*—laburnum, yellow iris, turnip, buttercup; *blue*—ground ivy, bluebell, speedwell, violet; *lilac*—syringa.

If viewed from above, or with calyx and corolla removed (Fig. 58, II.), we see inside the flower a number of small, usually yellow, bodies (*s*, Fig. 58). They are attached to long delicate stalks, and if pressed burst and set free a quantity of yellow dust. They are termed stamens, and are composed of two parts, the *filament* (*f*) and the *anther* (*a*), which is rounded or oblong in shape.

In the middle of the flower is a small round body, green in colour, called the *ovary*. The ovary ends above in the thread-like *style* (*g*, Fig. 58), the top of which is expanded so as to form the *stigma* (*n*). The ovary itself cannot be seen in Fig. 58. In Fig. 59 we see the ovary of a pink removed from the flower—calyx, corolla, and stamens have all been cut away. The ovary (*f*) in this case has three stigmas (*g*), not merely one like Weigelia. The ovary by-and-by forms the fruit; it contains a number of small white grains—the *seed*.

FIG. 59.
Ovary (*f*) of *Silene inflata*. *s* Flower-stalk, *r* Receptacle, *g* Style; nat. size.

In Fig. 59, *s* indicates the stem which bears the flower, viz., the *flower-stalk*. This is frequently, though not always, expanded at the upper end, where it forms what is called the *thalamus* or *receptacle*, which supports all the parts of the flower—sepals, petals, stamens, and ovary.

Although one would scarcely infer from their appearance that the stamens and ovary were *leaves*, they are nevertheless to be classed as such. Evidence for this statement is drawn from the fact that in certain flowers we find stamens half transformed into petals. This transformation or metamorphosis can be produced in many flowers by special culture,—in fact the phenomenon may be observed in most of those garden flowers which we call *double*. If this *doubling* is perfect,

all the stamens will have become transformed into petals. Usually, however, it does not go so far, and we thus find stamens in every stage of transition. A good example is found in mock orange blossom (Fig. 60). The illustrations show every stage between the perfect stamen (I.) and the perfect petal (VI.) The filament is indicated by the letter *f*, the anther by *b*; in VI. the filament is represented by the midrib.

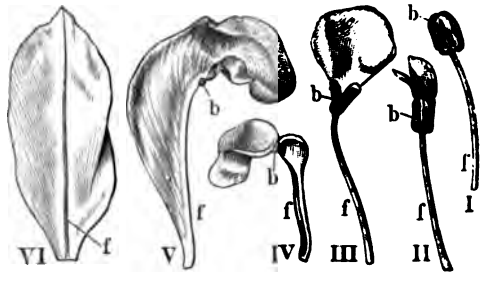


FIG. 60.

Transformation of stamens into petals (read from I. to VI.); twice nat. size. *f* Filaments, *b* Anther.

The position in which the floral envelopes may stand with regard to the ovary differs much in different flowers. If calyx and corolla are united *to the top* of the ovary, the ovary being thus placed *beneath* them (Figs. 61, 62), the floral envelopes (*k b*) are said to be *epigynous*, the ovary (*f*) *inferior*. If, again, the floral envelopes arise from under the ovary, the ovary being thus enclosed by them (Fig. 64), the floral envelopes (*b*) are said to be *hypogynous*, and the ovary (*f*) *superior*. If the calyx and corolla arise round the ovary, the floral envelopes (*k b*) are said to be *perigynous*, the ovary (*f*) *mediate* or half inferior (Fig. 63).

FIG. 61.

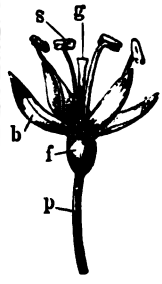


FIG. 62.

Epigynous corolla. Fig. 61.—Willow-herb (*Epilobium angustifolium*), longitudinal section; nat. size. Fig. 62. — Dogberry (*Cornus sanguinea*), three times enlarged; *p* Flower-stalk, *v* Bract, *f* Ovary, *k* Calyx, *b* Corolla, *s* Stamens, *g* Stigma.

EXAMPLES.—Flower *epigynous*, ovary *inferior*—epilobium, dogberry, apple blossom, pear blossom, canna, Weigelia, orchis, aristolochia; flower *perigynous*, ovary *mediate*—mock orange blossom; flower *hypogynous*, ovary *superior*—tulip, lily of the valley, pink, buttercup, water lily, poppy, celandine.

The sepals of the calyx, the petals, even the stamens, are

frequently not distinct from one another, but are wholly or in part *united*. The sepals of the calyx, or the petals of the corolla,

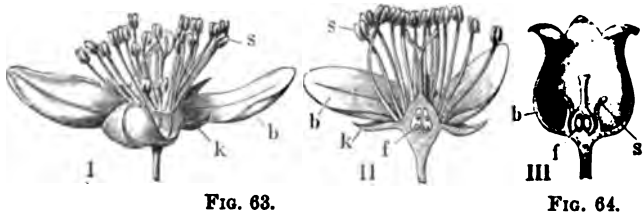


FIG. 63. FIG. 64.

Perigynous and *hypogynous* arrangement. Fig. 63 (I. II.).—Perigynous flower of mock orange (*Philadelphus coronarius*). I. Viewed from outside; II. Longitudinal section; nat. size. Fig. 64 (III.).—Flower of lily of the valley (*Convallaria majalis*), longitudinal section; twice nat. size; *k* Calyx, *b* Corolla, *s* Stamen, *f* Ovary.

&c. may be united *inter se*, or the different parts may be united with each other, *e.g.*, calyx with corolla, corolla with stamens, &c.

1.—*The Floral Envelopes.*

Under this title is included all that set of organs whose function it is to form a protection for the other parts of the flower which lie within them. The larger the floral envelopes the better they fulfil this function; if small, they are less serviceable.

EXAMPLES.—*Flowers with large floral envelope*—tulip, lily, blue-bell, foxglove, larkspur, monk's-hood; *flowers with small envelopes*—elm, oak, stinging nettle, hemp.

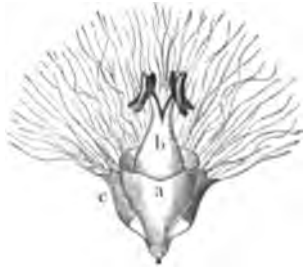


FIG. 65.

Female flower of black poplar (*Popularis nigra*). *a* Cup-shaped receptacle; *b* Ovary with two cleft stigmas; *c* Protective scales.

When the floral envelopes are large (well developed), the corolla, and occasionally also the calyx, are of a brilliant colour; these are *flowers* in the true sense of the word. We must, however, remember that the flower may also be green like the leaves, and scarcely apparent at all.

Very occasionally the floral envelopes *are entirely wanting*, in which case the flower consists only of stamens and ovary (*e.g.*, black poplar, Fig. 65).

The floral envelopes may be either *single* or *double*. When

double the outer is termed the calyx, the inner the corolla, as has been already said (p. 38).

If the floral envelopes are double, it is easy to distinguish one from the other when they are of different colours. Sometimes, however, the calyx is of the same colour as the corolla, in which case the flower is said to have a *perianth*. They are then usually to be distinguished either by their *position* or by their *shape*. An example of a flower in which calyx and corolla look alike is the tulip, which is shown (somewhat reduced) in Fig. 66. The

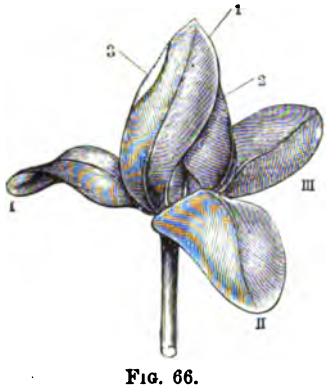


FIG. 66.

Perianth of tulip (*Tulipa Gesneriana*). I., II., III., Calyx, or external envelope; 1, 2, 3, Corolla, or internal envelope; § nat. size.

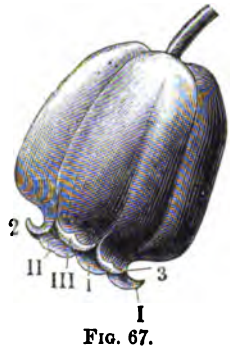


FIG. 67.

Cup-shaped flower of bell hyacinth (*Muscari racemosum*), seven times enlarged. I., II., III., Sepals of calyx; 1, 2, 3, Petals of corolla.

leaves opened downwards are the sepals (I., II., III.), those closed are the corolla (1, 2, 3). All six leaves have the same colour and almost the same size, but the sepals differ from the petals in being broader, and in having a stronger midrib, as may be seen in the figure.

EXAMPLES.—*Flowers with perianth* are tulip, fritillary, snake's-head, lily, star of Bethlehem, rush.

In many flowers with double floral envelopes, calyx and corolla have grown together. If the union is of a very intimate nature, calyx and corolla have the same colour—brilliant, like that of all typical corollas. An example of this is *Muscari racemosum* (Fig. 67). The three sepals (I., II., III.) and the three petals (1, 2, 3) are completely united. They form a hollow cup, which is closed except at the edge. There the sepals and petals cease to be united, and form the six-toothed rim of the flower; both are dark blue in colour. Lily of the valley and hyacinth have also flowers of this kind.

When there is but *one* floral envelope, either calyx or corolla is absent. Such flowers are also said to have a *perianth*. Single perianths are rare: one is seen in Fig. 68. The perianth (*p*) has three leaves, *s s* are the stamens. The perianth is small, unattractive, and greenish in colour. The anemone (Fig. 69) has a large, distinct single perianth; it is formed by six ovate white petals.

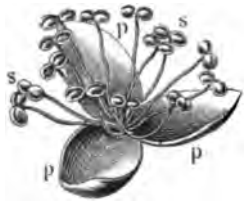


Fig. 68.

Fig. 69.

Single Perianth. Fig. 68.—Mercury (*Mercurialis annua*), magnified eight times; *p* Leaves of perianth; *s s* Stamens. Fig. 69.—Wood anemone (*Anemone nemorosa*); nat. size.

Examples. — *Single perianth*—goose-foot, aristolochia, anemone, spurge, hemp, mercury, stinging nettle, hazel-wort.

In flowers with a double perianth it often is not easy to distinguish calyx from corolla; in all other flowers with two floral envelopes they are easily to be recognised by differences in form and colour.

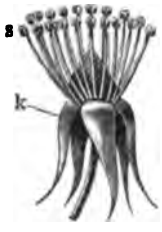


Fig. 70.

Calyx (*k*) of raspberry (*Rubus Idæus*). *s* Stamens; twice nat. size.

A. *The Calyx.*—The calyx is the *outermost* envelope of the flower; it consists of a circle of leaves arranged round the flower-stalk in a whorl (Fig. 70). The sepals of which the calyx is composed are frequently green in colour. Their shape is simple, mostly pointed or lanceolate; a midrib is frequently present.

If the sepals are separate from each other throughout their whole length, they are said to be *free* (*e.g.*, Fig. 70, which represents a five-cleft calyx). More frequently, however, the sepals are partly or entirely united, *i.e.*, the calyx is *gamosepalous*. If they are united only near their bases the calyx is said to be *parted* (*e.g.*, Fig. 71, II.; calyx five-parted). If the union is so complete as to leave only the points free, the calyx is said to be *toothed* (*e.g.*, Fig. 71, III.; calyx five-toothed). More rarely we find the sepals united at their bases, while the points are connected by a delicate, transparent membrane (Fig. 71, IV., membranous calyx).

EXAMPLES.—*Sepals free*—buttercup (five), wallflower (four); *parted*—wild rose, mullein (five-parted); *toothed*—thorn apple, hen-bane, bladder campion, mallow, bindweed; *membranous*—sea pink.

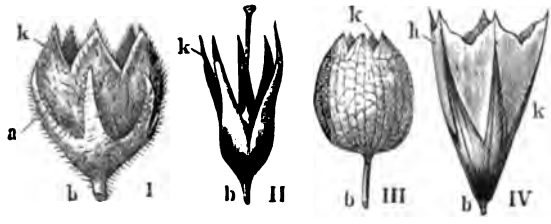


FIG. 71.

Calyx. I. Mallow (*Malva sylvestris*); thrice nat. size. II. Mullein (*Verbascum Thapsus*); thrice nat. size. III. Bladder campion (*Silene inflata*); nat. size. IV. Sea pink (*Armeria vulgaris*); six times enlarged. *b* Flower-stalk, *a* Epicalyx; *k* Calyx; *h* Membranous part of calyx.

When there is outside the calyx a whorl of green, sepal-like scales, forming as it were an outer calyx, the structure receives the name of *epicalyx* (Fig. 71, I. *a*).

EXAMPLES.—An epicalyx is found on the potentilla, mallow, and sea-pink. (In the last case it consists of bracts; in the second of a bract with its stipules, in the first of the united stipules of the sepals.)

In many plants the calyx falls off as soon as the flower opens; it is *caducous*. The flowers of the poppy and of the celandine have a two-leaved, bright green calyx, which falls off as the corolla expands, so that the fully opened flower has the appearance of a perianth. The calyx, therefore, is to be sought for only on the unopened bud. The opposite of this is the *persistent* calyx, which does not fall off with the petals and stamens, but is to be found even on the ripe fruit. Apples and pears afford the best examples of the persistent calyx; it appears as a small bunch of withered leaflets at the top of the fruit. The strawberry and the rose also have a persistent calyx. In the rose the so-called dog-hip, assuming a fleshy texture and enclosing a number of seeds (see *Fruit*), is often regarded as modified from the calyx.

According to its shape, the free-leaved or polysepalous calyx is *rotate* or *flat*, the *gamosepalous* is *campanulate* or *bulged* (Fig. 71, I.), *cup-shaped, inflated* (Fig. 71, III.), *funnel-shaped* (Fig. 71, IV.), *tubular, cylindrical*, and occasionally quite *irregular* (monk's-hood).

Peculiar forms of calyx are the *labiate* calyx, the *spurred* calyx, and the *downy* calyx.

(1.) The *labiate* calyx (Fig. 72) is one in which the sepals are united, and which is divided into two opposite parts, which meet each other somewhat after the fashion of lips. The upper part (*a*) is called the *upper lip*, the under part (*b*) the *under lip*.

(2.) The *spurred* calyx (Fig. 73) has likewise the sepals united, as a rule. In it one or more sepals seem to coalesce, so as to form a long hollow tube (*n*) closed at the lower end.

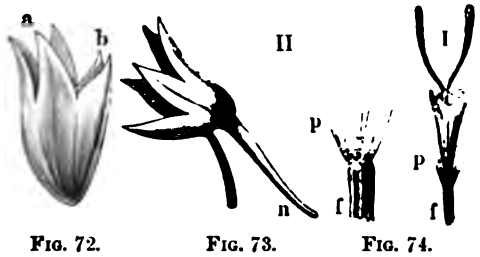


FIG. 72. FIG. 73. FIG. 74.

Fig. 72.—Labiate calyx of sage (*Salvia officinalis*). *a* Upper lip; *b* Under lip; three nat. size. Fig. 73.—Spurred calyx (*n*) of monk's-hood (*Tropæolum majus*); nat. size. Fig. 74.—(I., II.) Pappus of water-hemp (*Eupatorium cannabinum*); in I. twice, in II. four times nat. size.

(3.) The most extraordinary of all the forms of the calyx is the *downy* calyx, or *pappus*. (Gr. *pappos*, Lat. *pappus*, the name applied, even by the ancients, to plants having a downy calyx, *e.g.*, dandelion, &c.) The downy calyx does not consist of green leaves, but of numerous delicate greyish hairs. Each hair is usually fringed on both sides by finer hairs, so that they look like small feathers. The pappus stands erect, and does not fall off with the flower, but remains attached to the fruit, to which, when fully ripe, it serves as a means of transport (Fig. 74). (Many, however, regard the pappus as not corresponding to the calyx, but merely to epidermic hairs.)

EXAMPLES.—Calyx *rotate* or *flat*—buttercup, strawberry, speedwell, crane's-bill; *cup-shaped*—rose; *campanulate* or *bulged*—campion; *tubular* or *cylindrical*—lungwort, gentian, thorn apple, garden pink; *labiate*—dead-nettle, prunella, thyme, sage; *spurred*—Indian cress; *downy* (pappus)—dandelion, thistle, goat's-beard.

B. *The Corolla.*—The corolla or inner whorl of the double floral envelope can be much more easily distinguished from the ordinary foliage leaves than the calyx. The petals of the corolla are delicate in texture, often extremely beautiful and brilliant in colour. Usually the petals of the corolla are *entire*, roundish, elongated, ovate, or lanceolate in shape (Figs. 61, 62, 63). Occasionally they are cleft (Fig. 75). Sometimes the lower part of the blade of a petal is suddenly tapered, when the tapered part receives the name of *claw* or *unguis;* the petal is then said to be *clawed* or *unguiculate*. The petals may be smooth and flat, or they may be crumpled in various ways.

The petals of the corolla are either separate or partly united. In the former case they are said to be *free*, and the corolla is *polypetalous* (or, better, *apopetalous*). Usually there are three, four, or five petals; in the latter case the flower is *gamopetalous* or *sympetalous*. If the petals are united only at their base, the corolla is said to be *parted* (three, four, or five parted, just like the calyx). However the petals are more often united in such a manner that only their *tips* remain free. These form what is technically termed the *limb* or *border;* according as it is made up of four, five, or more coalesced petals, it is called four, five, &c. *lobed* or *tipped*.

FIG. 75.

Flower of ragged robin (*Lychnis flos-cuculi*) with cleft petals; nat. size.

EXAMPLES.—*Polypetalous corolla* — buttercup, violet, strawberry, cherry; *gamopetalous*—primrose, lungwort, syringa, bilberry; *parted* —speedwell, nightshade.

Corollas are either *regular* or *irregular*. They are said to be *regular* when the petals are all of one shape and size, or when in gamopetalous flowers the lobes are all one shape and size. *Irregular* corollas are such as have some or all their petals of different shapes and sizes, or in gamopetalous flowers, such as have the lobes of different shapes and sizes. Flowers with a regular corolla have usually a regular calyx likewise; in flowers with an irregular corolla, the calyx is usually also irregular (*e.g.*, labiate flowers, &c.).

The forms of the regular corolla are very diverse. The principal are the following:—

1. *Rotate* (Fig. 76).—All the petals free, or only united at the base; flat shape, spread out all in one plane.

FIG. 76.

Rotate flower of borage (*Borago officinalis*); nat. size. (Hairs omitted to preserve distinctness.)

2. *Urceolate* (Fig. 77).—The petals united up to the tips, thus forming a hollow vase or urn. The throat (the opening at the summit) is narrow, and is formed by the extreme tips of the petals.

3. *Campanulate* (Fig. 78, Fig. 45).—The petals united up to the tips; they bulge out towards the summit, and narrow as they approach the stalk. The throat is surrounded by the free tips of the petals.

4. *Infundibuliform* or funnel-shaped (Fig. 79).—Similar to the foregoing, the united petals arranged in the form of an inverted

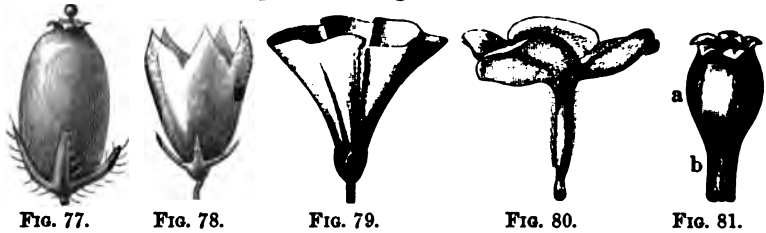


FIG. 77. FIG. 78. FIG. 79. FIG. 80. FIG. 81.

Forms of Corolla. Fig. 77.—Urceolate flower of a heath (*Erica Tetralix*). Fig. 78.—Campanulate flower of blue-bell (*Campanula rotundifolia*). Fig. 79.—*Funnel-shaped* flower of convolvulus (*Convolvulus arvensis.*) Fig. 80.—*Salver-shaped* flower of phlox (*Phlox paniculata.*) Fig. 81.—*Tubular bellflower* of comfrey (*Symphytum officinale*); all nat. size, except Fig. 77, which is magnified three times.

cone, *i.e.*, having straight outline gradually narrowing towards the stalk. The throat is either like that of a campanulate flower, or the petals are united throughout, forming an entire rim.

5. *Salver-shaped* (Fig. 80).—Petals united so as to form a hollow tube, with expanded surface, the upper parts of the petals alone being free.

6. *Tubular campanulate.*—The united part of the petals form an inflated tube, so that the flower may be said to have features characteristic of both the salver-shaped and the campanulate varieties, *e.g.*, in Fig. 81 the flower is campanulate at *a*, tubular at *b*.

All the above forms of corolla are likewise to be found among polypetalous flowers.

EXAMPLES.—*Rotate*— buttercup, borage, forget-me-not, speedwell; *campanulate* — blue-bell; *funnel-shaped* — convolvulus, bindweed; *tubular*—phlox, wild bugloss; *tubular campanulate*—comfrey; *urceolate*—bilberry, heath.

The *forms of the irregular corolla* are just as varied as those of the regular. Many flowers are only *slightly* irregular; their petals may differ somewhat in size and shape, but this difference is not so marked that we can call the flower quite irregular (Fig. 84). Tubular campanulate and other corollas are occasionally irregular, because the free edges of the petals forming the throat of the flower are not alike in size (Fig. 85).

FIG. 82.

Spurred corolla of *Corydalis bulbosa*; nat. size. *s* Spur.

EXAMPLES.—*Slightly irregular*—carrot, parsnip, hemlock, speedwell; *irregularly tubular*—foxglove.

The principal forms of the perfectly irregular corolla are the following:—

(1.) *Spurred* (Fig. 82).—The corolla may vary much in shape. One (*s*, Fig. 82) or more of its petals are prolonged so as to form a closed tube, which may be either long or short. This tube is the *spur*. The petals may be either free or united.

(2.) *Ligulate* or *strap-shaped* (Fig. 83).—In the figure we see the corolla to be composed of five united petals. At the base

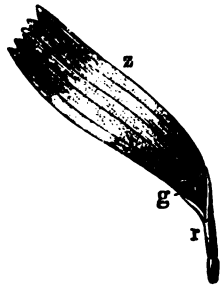


FIG. 83.

Ligulate corolla of the chamomile (*Anthemis arvensis*); twice nat. size. *r* Tubular portion, *z* Ligulate portion, *g* Style and Stigma.

FIG. 84.

FIG. 85.

Fig. 84.—*Rotate corolla* of speedwell (*Veronica Chamædrys*). Fig. 85.—*Tubular floret* of the cornflower (*Centaurea cyanus*); twice nat. size.

they form a short tube (*r*), and are prolonged upwards into a narrow linear leaf or strap (*z*). At the summit of the latter are five points corresponding to the five petals, out of which this peculiar corolla is formed.

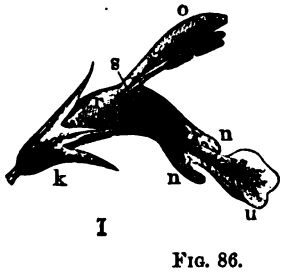
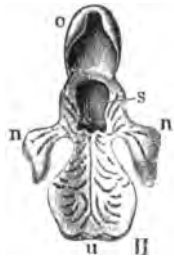


FIG. 86.



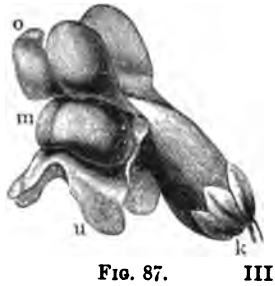


FIG. 87. III

Fig. 86.—Labiate corolla of hemp-nettle (*Galeopsis versicolor*); thrice nat. size. Fig. 87.—Personate corolla of snapdragon (*Antirrhinum majus*); nat. size. *k* Calyx, *r* Tubular portion of corolla, *s* Throat, *u* Lower lip, *n* Lobes of the same, *o* Upper lip.

(3) *Labiate* (Fig. 86, I. II.).—Flowers with a labiate corolla are, like those above mentioned, gamopetalous. Below, the

petals form a tube (tubular portion, *r*); at the throat (*s*) the free edge of the tube divides into two halves (*o n*). These are placed opposite each other, one above, one below. The upper half, which is frequently much bulged, is called the *upper lip* (*o*); the lower, which is elongated, and very often cleft, is named the *lower lip* (*n*). A flower of which the throat (*m*, Fig. 87) is closed by a projection of the lower lip, called the palate, is said to be *personate* or *masked*.

(4.) *Papilionaceous.*—Flowers with a papilionaceous corolla (Fig. 88) have five *free* irregularly shaped petals. The upper and largest petal is called the *vexillum* or standard (*a*, I. II.), the two at the sides are the *alæ* or wings (*b*, I. III.), and the two lower (united) together form the *carina* or keel (*c*, I. IV. V.). The last named surrounds the stamens and the pistil (V.). The calyx (*d*) of papilionaceous flowers is usually labiate.

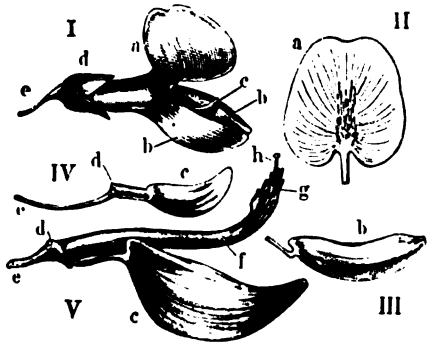


Fig. 88.

Papilionaceous flower of laburnum (*Cytisus laburnum*). I. Entire flower; II. Vexillum; III. Alæ; IV. Carina—nat. size; V. twice nat. size. *a* Vexillum, *b* Alæ, *c* Carina, *d* Calyx, *e* Flower-stalk, *f* Filament, *g* Anther, *h* Pistil.

Examples. — *Spurred*—fumitory, corydalis, violet, toadflax; *ligulate* — daisy, aster, dandelion, sunflower, goat's-beard, chicory; *labiate*—clover, stachys, sage, nettle, ground ivy; *personate*—snapdragon, toadflax; *papilionaceous*—laburnum, bean, pea, robinia, clover, lupin.

Fig. 89.

Flower of red campion (*Lychnis divrna*); nat. size; *n* Corona.

Corona. — By the term *corona* is meant certain outgrowths from the petals, having the same characteristics as these, and even the same shape. It forms as it were a corolla within the corolla (Fig. 89, *n*). In some plants the parts of the corona are free, and form a ring of small, frequently hairy, scales around the throat of the corolla. Sometimes they are united, funnel-shaped, and pretty often of considerable size.

EXAMPLES.—In the narcissus the corona is large and united; in the red campion (Fig. 89) the parts are separate.

2.—*The Stamens.*

The stamens (*s*, Fig. 58, 61-64) lie within the floral envelopes, next to the corolla. Although to all appearance very unlike leaves, they are yet, as already seen (Fig. 60), indisputably to be considered as leaf structures. The number of stamens usually corresponds to the number of petals, or it may exceed that of the petals, but seldom falls below it.

EXAMPLES.—*Flowers with fewer stamens than petals*—speedwell (Fig. 84), sage, valerian, syringa. *Stamens and petals equal*—dogberry (Fig. 62), Weigelia (Fig. 58), carrot, violet. *Stamens more numerous than petals*—mock orange (Fig. 63), buttercup, rose, cherry blossom, meadow-sweet, strawberry.

The stamens are either inserted on the receptacle or are adnate to the calyx or corolla. According to the insertion of the stamens, we have flowers classified as *thalamifloral*, *calycifloral*, or *corollifloral* (Fig. 90; Figs. 91-93).

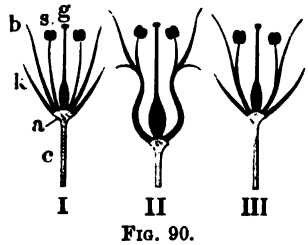


FIG. 90.

Classification of flowers according to insertion of stamens. I. Thalamifloral; II. Calycifloral; III. Corollifloral. *c* Flower-stalk, *a* Receptacle, *k* Calyx, *b* Petals, *s* Stamens, *g* Pistil.

1. *Thalamifloral* (Fig. 90, I., Fig. 91).—Flowers are said to be *thalamifloral* when the sepals (*k*), petals (*b*), stamens (*s*), and ovary (*g*) arise from the top of the expanded leaf-stalk—the thalamus or receptacle (*c*, comp. Fig. 59, *r*).

2. *Calycifloral* (Fig. 90, II., Fig. 92).—Flowers are said to be *calycifloral* when only the calyx and the ovary are inserted on the receptacle. In this case the calyx is frequently cup-shaped, and has the petals and stamens emerging from its throat.

3. *Corollifloral* (Fig. 90, III., Fig. 93).—Flowers are said to be *corollifloral* when the calyx, petals, and ovary are inserted on the receptacle, the stamens being attached (usually adnate) to the corolla.

Note.—The word *thalamifloral* is derived from Lat. *thalamus* (Gr. *thalamos*), a receptacle, and *flos*, a flower. *Calycifloral* comes from Lat. *calyx* or *calix* (Gr. *kalyx*), a cup, and *flos*. *Corollifloral* is derived from Lat. *corolla*, dim. of *corona*, a crown or wreath, and *flos*.

If we remove the petals from a corollifloral flower, we find that the stamens, being adherent, come away along with them. If in a calyciflora flower we remove part of the calyx, we find both stamens and petals adhering to it. In a thalamifloral flower we can remove all the sepals and petals, after which we shall have the stamens and the ovary still adhering to the receptacle.

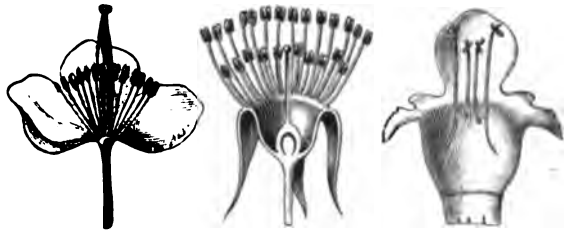


FIG. 91. FIG. 92. FIG. 93.

Fig. 91.—Thalamifloral flower of celandine (*Chelidonium majus*); nat. size. Fig. 92.—Calycifloral flower of cherry (*Prunus Cerasus*); twice nat. size. Fig. 93.—Corollifloral flower of prunella (*Prunella vulgaris*); in section, nat. size.

EXAMPLES.—*Thalamiflorals*—anemone, buttercup, marsh marigold, poppy, celandine, lady's smock, campion, lime; *calyciflorals*—laburnum (Fig. 88), cherry, strawberry, bramble, rose, bilberry; *corolliflorals*—forget-me-not, lungwort, potato, dead-nettle, speedwell.

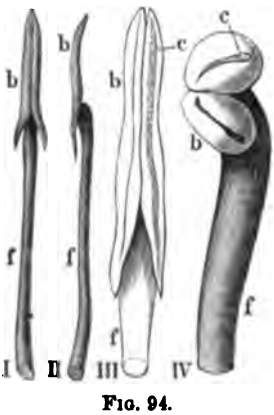


FIG. 94.

Stamens.—I.-III. Gladiolus (*Gladiolus imbricatus*); IV. Snap-dragon (*Antirrhinum majus*). I. II. nat. size; III. three times enlarged; IV. five times enlarged. *f* Filament, *b* Anther, *c* Slit, along which anthers open.

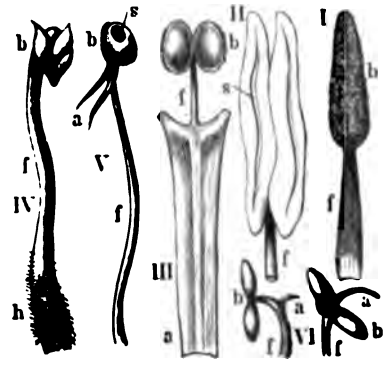


FIG. 95.

Stamens.—I. Tulip (*Tulipa Gesneriana*); twice nat. size. II. Canary grass (*Phalaris arundinacea*); four times nat. size. III. Deutzia (*Deutzia glabra*); four times enlarged. IV. Broom-rape (*Orobanche rubra*); three times nat. size. V. Heath (*Erica Tetralix*); three times nat. size. VI. Prunella (*Prunella vulgaris*); five times nat. size. *f* Filament, *b* Anther, *s* Slit, *a* Appendage, *h* Hairs.

A stamen consists of two parts, the filament and the anther, the latter being borne on the point of the former.

A. *The Filament.*—The filament (*f*, Fig. 58, 60, 94, 95) takes its name from its thread-like appearance. It is usually cylindrical in shape, and tapers towards the summit (*f*, Fig. 58, III. IV.; Fig. 94, I. to III.; Fig. 95, V. VI.). It is whitish or yellowish in colour, occasionally of some darker tint (*e.g.*, dark blue in the tulip, Fig. 95, I.). Sometimes the filament is flattened laterally (Fig. 95, III., *a*); it may also bear *appendages* of different shapes and sizes in the neighbourhood of the anther (*a*, Fig. 95, V. VI.).

When all the filaments in a flower are separate from each other they are said to be *free;* when they coalesce by their bases, or throughout their whole length, they are said to be *united.*

Stamens may be united in several ways.

(1.) *All* the filaments in a flower may be adherent to one another. In this case the filaments are united so as to form a cylinder or tube, which bears at its upper end numerous anthers on the free points of its filaments. The filaments are then said to form a *bundle* (Fig. 96, I.), and the stamens are called *monadelphous.*

(2.) *All* the filaments of the flower may be united, but in such a way that they do not form a single bundle, but two, three, or five. Two, three, four, or many stamens may coalesce so as to form a bundle (Fig. 96, II., III.). They are then said to be *polyadelphous.*

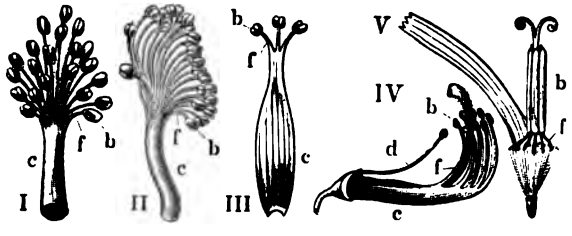


FIG. 96.

Union of Stamens.—I. Filaments forming a single bundle; II. One of the five bundles from the flower of *Vismia;* III. One of the bundles from *Corydalis bulbosa;* IV. Two bundles (9 + 1) from *Colutea arborescens;* V. Bundle of filaments united by the anthers from hawk-weed (*Hieracium umbellatum*). *b* Anthers, *f* Filaments, *c* Filaments united.

(3.) One filament (*d*) may be free; all the rest united to form one bundle. The number of filaments thus united is nine. This form of coalescence of the stamens is characteristic of most of the Papilionaceæ (Fig. 96, IV.), and is described as *diadelphous.*

EXAMPLES.—(1.) *a.* Five filaments in one bundle—bryony, cucumber, pumpkin, flax; *b.* ten filaments in a bundle—geraniums, crane's-bill; *c.* many filaments in a bundle—mallow, hollyhock.

(2.) *a.* Six filaments in two bundles—fumitory; *b.* eight filaments in two bundles—milkwort (*Polygala*); *c.* Many filaments in three or five bundles—St. John's worts.

(3.) Nine stamens united, a tenth free—clover, bean, lentil.

B. *The Anthers.*—At the summits of the filaments are the anthers. On each filament two, one to the right, the other to the left (Fig. 58, 94, 95). They may be elongated and narrow (Fig. 58, 94, I. to III., 95, II.), or rounded (Fig. 94, IV., 95, III., V.), or angular; in the pumpkin, cucumber, and such-like plants they are variously twisted.

While the partial or entire coalescence of filaments is comparatively common, the coalescence of anthers is extremely rare. It is characteristic of the *Compositæ*, however. In Fig. 96, V., we have the five stamens of hawk-weed. The filaments (*f*) are perfectly free; the anthers (*b*) are united throughout their whole length.

When the flower opens the anthers are usually of a bright yellow colour, the upper surface perfectly smooth and flat, as is easily seen when they are viewed with a lens. After a time, however, each anther bursts open along its entire length by means of a slit (*c*, Fig. 94, *s*, Fig. 95). Through this slit is shed a large quantity of fine floury dust, the *pollen* (from the Lat. *pollen*, fine flour). The pollen is of a bright or deep yellow colour, and is usually somewhat sticky, so that after it is set free from the anther, it remains adherent to the external surface for a considerable time, covering it entirely.—(See *b*, Fig. 95, III., and *b*, Fig. 95, I.) In many plants, however, the pollen is not sticky, in which case, when the plant is shaken, it rises as a dusty cloud of yellow grains, to fall again, often in showers, at some distance, (*e.g.*, pollen of hazel, elm, and pine).

Some idea may be formed of the enormous quantity of pollen formed in many flowers by observing what happens when we shake a hazel-tree when in blossom. From every catkin rises a cloud of dust, every particle of which is formed by a single pollen grain. Each grain is so small as to be invisible to the naked eye, and even with a lens is only distinguishable as a tiny dot. A still greater quantity of pollen is obtainable from pines and firs. When in spring the wind blows over a pine wood, the pollen is borne along as a thick yellow cloud. The ground beneath the pine trees is frequently quite covered by the

golden dust, as is also the surface of every pool, marsh, and ditch in the neighbourhood. At such times country folks are wont to say it has been raining sulphur.

The opening of the anther is effected in most cases by means of a longitudinal slit (Fig. 94, Fig. 95, II.). Occasionally the slit is transverse, or a passage may be made for the pollen by a round opening (Fig. 95, V.). The scattering of the nettle pollen is accomplished in a very remarkable manner. In the bud the parts of the small green perianth of the flower are folded inwards, and beneath them lie the four stamens, which from their appearance have been aptly compared to springs. When the flower opens and the petals begin to expand a little, thus relaxing their hold on the stamens, the latter suddenly spring up; by this violent movement the anthers are burst open, and the pollen is scattered far and wide.

3.—*The Ovary or Pistil.*

The ovary lies in the centre of the flower, forming there a green knob-like prominence. It does not fall off with the other parts of the flower, but remains long after they have died off, and develops into the *fruit*. According to the relation which

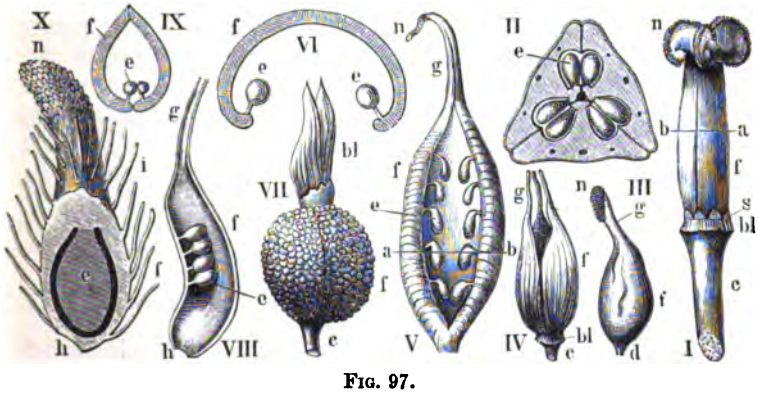


FIG. 97.

Ovaries.—I. Tulip (*Tulipa Gesneriana*). 1. General appearance (nat. size). II. Cross section (four times nat. size). III. *Thalictrum aquilegifolium* (five times enlarged). IV. Marsh St. John's wort (*Hypericum Elodes*), general appearance (four times enlarged). V. Carpel (seven times enlarged). VI. The same in cross section (ten times enlarged). VII. *Canna Indica* (nat. size). VIII. Green hellebore (*Helleborus viridis*), longitudinal section. IX. Transverse section; three times enlarged. X. *Hepatica triloba*, partly open; five times enlarged. *c* Flower-stalk; *d* Fruit-stalk; *bl* Point of insertion of leaves; *s* Ditto of stamens; *f* Ovary; *g* Style; *n* Stigma; *e* Seed; *i* Hairs; *a b* shows point of section.

its position bears to that of the other organs of the flower, the ovary is spoken of as *superior* or *inferior*, as has already been

explained. In the ovary the following parts are to be distinguished: the *ovary proper*, the *style*, the *stigma*, and the *seed* (Fig. 97).

A. *The ovary* in the restricted sense (*f*, Fig. 97) is composed of one or more strong, fleshy, leaf-like structures (pistil leaves or carpels), which have grown together by their margins. Externally the line of coalescence is marked by ridges or *sutures* (Fig. 97, IV., VII.). Ovaries which are composed of only one carpel are called *monocarpellary* or *simple* (Fig. 97, VIII.-X.); ovaries composed of several carpels are called *polycarpellary* or *compound* (Fig. 97, I. II.).

If the ovary is *simple* (Fig. 97, VIII.) the margins of the leaf forming the single carpel are incurved, and coalesce in the long direction (along *e*). There we find the *ridge* or *suture* formed by the junction of the margins; thus externally simple ovaries have one suture.

If the ovary is *compound* (*e.g.*, tricarpellary, as in Fig. 97, IV.), the leaves or carpels coalesce with their margins side by side (right margin of the first joins with left of second, &c.), and form a sac whose walls are made up of as many parts as there are carpels. A corresponding number of sutures may be seen on the outside.

The relations of these parts are well brought out in those compound ovaries, whose carpels have only partly coalesced. In Fig. 97, IV., we have the ovary of the Marsh St. John's wort (*Hypericum Elodes*). In it we see the three carpels which have coalesced up to about the point *f*; in the upper part, *g*, they are free and plainly distinguishable one from another. In Fig. 97, V., we have one of the three carpels by itself. The ovary of the tulip is also composed of three carpels, but in this case they have completely coalesced (Fig. 97, I. II.).

The manner in which the union of the carpels is brought about is usually the following (by way of example let us take a three-celled ovary, Fig. 98):—

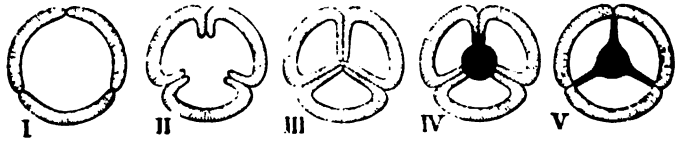


FIG. 98.

Arrangement of Carpels.—I. One-celled ovary. II. Incipient three-celled ovary (partitions incomplete). III. IV. V. Forms of fully developed three-celled ovary.

(*a.*) First, the carpels or leaves of which the pistil is composed have their contiguous margins united without incurving (Fig. 98, I.), and form what is called a compound, one-celled, or unilocular ovary.

(*b.*) Next, the margins are slightly turned in, and the turned-in parts coalesce (Fig. 98, II.). The ovary is still one-celled, but incomplete partitions extend from its walls towards the centre; there are as many partitions as there are carpels in the ovary. Such an ovary is said to be incompletely several-celled.

(*c.*) Next, the margins are much turned in, so much, indeed, that their edges meet in the middle, where they coalesce (see *ante*, simple one-celled ovary). In addition to this, the carpels grow together all along their turned-in surfaces (Fig. 98, III.). A several-celled ovary is thus formed which has as many cells as there are carpels in its structure.

Several-celled ovaries may also arise in the following manner:—

(*d.*) The carpels coalesce, as in *b*. Besides partially coalescing with one another, they unite with a thickish axis, which stands up in their midst. This axis, which traverses the ovary throughout its entire length, is a pillar-like prolongation of the receptacle—not a part of the carpels, but a continuation of the flower-stalk.

(*e.*) The carpels unite, as in *a*; throughout the sac thus formed the flower-stalk is again prolonged, and from it wing-like partitions run to meet the carpels. The ovary is thus divided into two or more cells, according to the number of the partitions (Fig. 98, V.).

The partitions which divide the ovary into cells are termed *dissepiments*.

EXAMPLES.—*One-celled* or *simple ovaries*—buttercup, Thalictrum (Fig. 97, III.), green hellebore (Fig. 97, VIII.), Hepatica (Fig. 97, *x*), arrow-head, cherry; *compound:* (*a.*) *one-celled*—tooth-wort (Fig. 99, IV., composed of two carpels), violet (Fig. 99, II., composed of three carpels); grass of Parnassus (*Parnassia palustris*, composed of four carpels), primrose (Fig. 99, III., composed of five carpels), poppy (incomplete many-celled, composed of an indefinite number of carpels); (*b.*) *several-celled*—carrot, potato, convolvulus (two-celled); tulip (Fig. 97, II.), canna (Fig. 99, I.), iris, fritillary (three-celled); mock orange blossom, holly, heath, bilberry (four-celled); apple blossom, crane's-bill (five-celled); water lily (many-celled).

Commonly there is only one ovary in a flower, occasionally several or many. In this case the ovaries are simple, and stand close beside one another.

EXAMPLES. — *Four ovaries* — dead-nettle, ground ivy, lungwort; *many*—buttercup, strawberry, arrow-head.

The shape of the ovary may be round, oval, cylindrical, three, four, five, or more cornered, flattened, &c. Usually it somewhat resembles the shape of the fruit which is by-and-by to be developed from it.

B. *The Style and Stigma.*—At the upper part of the pistil we find a spot which is easily recognised by its roughness or hairiness. Further, its surface, if the flower is fully open, is usually covered with pollen. The *stigma*, as this part is called, has also a peculiar form, which distinguishes it from other parts of the pistil (*n*, Fig. 58, 97). In some cases the stigma is found directly on the summit of the ovary (*e.g.*, in the poppy, yellow water lily, tulip, Fig. 97), but more usually we find between the ovary and the stigma a thread-like structure, the *style* (*g*, Fig. 58, 61, 62, 97, III., IV.) The style may be short, moderately long, or very long (meadow saffron, crocus), its length frequently corresponding to that of the flower (Fig. 58). In shape it is usually tubular, cylindrical, or angular, rarely leaf-like (*e.g.*, iris). Its surface is frequently beset with numerous hairs, and in many cases it is traversed internally by a *canal*, so that the whole forms a sort of tube. A pistil has either *one* or *several* styles. The single style may be *simple* or *branched*. When branched, each branch has a stigma. These are usually equal in number to the number of carpels (Figs. 59, 97, IV.); that is to say, each style is simply the prolongation of a single carpel (Fig. 97, IV. V.).

The *stigma* varies much in shape; the more important forms will be considered hereafter.

EXAMPLES.—*Ovaries with single simple styles*—fritillary, primrose, violet, pennyroyal (in this plant four carpels have a *common* stigma), laburnum (Fig. 88, V.); simple ovary with *four-branched* styles—mock orange blossom; ovaries with *several* styles—flowers of the pink order, *e.g.*, bladder campion (Fig. 59, three styles), catchfly (*Lychnis viscaria*, five styles).

C. *The Ovules.*—In the cells of the ovaries are found the *ovules*. These are small, rounded or oval, white bodies, with or without a short stalk, but in any case attached to the inner surface of the carpels (*e*, Fig. 97, II., V., VIII., X.). When the

ovary develops into the fruit the ovules form the *seed*. In the more simple forms of ovary there is often but one ovule, in which case the ovary is said to be *one-seeded* (Fig. 97, X., *e*); more frequently, however, the ovary contains several or many ovules (Fig. 97, VIII., *e*). In several-celled ovaries each cell contains one or more ovules (Fig. 97, II.) All ovaries containing more than one ovule are said to be several or many-seeded, as the case may be.

EXAMPLES.—*One-celled ovaries*—Hepatica, cherry, plum, buttercup (with *one* ovule); violet, primrose, poppy, hellebore, bean (with *several* ovules). *Several-celled ovaries*—palms (in each cell a *single* ovule), tulip, iris, foxglove, water lily (in each cell *several* ovules).

Ovules may be attached to the ovary in various ways. The following are the most common forms of arrangement, or, as it is technically termed, *placentation*.

a. Central Placentation.—When the placentation is central the ovules are attached to the middle of the ovary. In *several-celled* ovaries this attachment takes place along the line of union of two dissepiments (Fig. 99, I., Fig. 97, III.). In *one-celled* ovaries the ovules are attached to the central column, formed by the prolongation upwards of the flower-stalk (Fig. 99, III.).

b. Parietal Placentation (Fig. 99, II.).—This form of placentation is most common in one-celled ovaries. The ovules (*e*) are attached to the walls (*f*) of the ovary, in the manner shown in the figure.

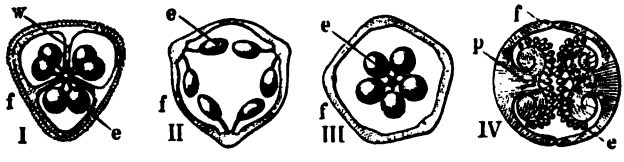


FIG. 99.

Placentation.—I. *Canna indica*, nat. size; II. Violet (*Viola odorata*), twice nat. size; III. Primrose (*Primula officinalis*), three times enlarged; IV. Toothwort (*Lathræa squamaria*), twice nat. size; *f* Wall of ovary, *w* Dissepiment, *p* *Placentæ*, *e* Ovules.

c. Ovules may be attached not directly to the central column or to the walls of the ovary, but to structures called *placentæ*, specially developed for their support. These may be either central or parietal. This is placentation in the true sense of the

word. In fact the term is only extended to other forms of attachment by courtesy, as it were, seeing that they have no distinct placentæ for the support of the ovules. In Fig. 99, IV., we have a one-celled ovary with two carpels; in the middle of each carpel is a thick fleshy prominence (*p*), the placenta with a large number of small ovules (*e*) attached.

EXAMPLES.—*Several-celled ovaries with central ovules*—tulip, fritillary, crane's-bill, fuchsia; *one-celled ovaries with ovules attached to central column*—primrose, catchfly, pink; *one-celled ovaries with parietal ovules*—violet, grass of Parnassus, gooseberry, orchis; ovaries with *placentæ*—mock orange blossom, campion, pumpkin.

Besides the forms of placentation already described, we may have the ovules attached all over the surface of the dissepiments (poppy, water lily).

4.—*Bisexual and Unisexual Flowers.*

All flowers in which both stamens and pistil are present are said to be bisexual or hermaphrodite. Just as in mathematics words are frequently expressed by signs (*e.g.*, ∠ for "angle"), so in botany the sign ☿ is used to denote a hermaphrodite flower. This sign is used alone or as a prefix to the word flower, thus,—☿ or ☿-flower = hermaphrodite flower.

All flowers are not bisexual. Some plants have *two kinds of flowers;* in the one we find only stamens, while the pistil is awanting; in the other we find only pistils, while the stamens are awanting.

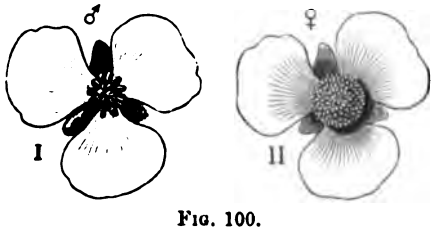


FIG. 100.
Male (♂) and female (♀) flower of arrow-head (*Sagittaria sagittæfolia*); nat. size.

Flowers containing *only stamens* are *male* (sign ♂); flowers containing only pistils are *female* (sign ♀). Flowers which are either male or female are said to be *unisexual.*

In Fig. 100, I., we have a male flower of arrow-head. Within the floral envelopes (sepals shaded dark, petals light) are seen numerous stamens, but no pistil. In the female flower (II.) there are no stamens, but numerous pistils.

Male and female flowers often grow together on the same plant, and even on the same branch; *e.g.*, in burr-reed (Fig. 101).

The male flowers (♂) grow in compact heads at the upper end of the branch, while the female (♀) are found in similar heads at the lower end. Plants in which stamens and pistils occupy different flowers on the same individual are called *monœcious*. On other plants stamens and pistils occupy different flowers on different individuals. The plants are then said to be *diœcious*, and the individuals either male or female.

Finally, some flowers have neither stamens nor pistils, but only calyx and corolla (Fig. 83). Such flowers are said to be *neuter*. All plants which bear *neuter* flowers have at the same time other flowers with stamens and pistils.

EXAMPLES.—Hermaphrodite-tulip, fritillary, anemone, fox-glove, primrose; *male and female flowers—monœcious*—burr-reed, birch, stinging-nettle, hazel, arrow-head, pumpkin, cucumber; *diœcious*—mistletoe, hops, poplar, dog's mercury; *neuter*—large outer flowers on composite head of the cornflower, and the outer and larger flowers of the guelder rose (the highly cultivated species of the guelder rose has *only neuter* flowers).

FIG. 101.

Burr-reed (*Sparganium simplex*), ♂ male, ♀ female flowers; nat. size.

5.—*Anthotaxis or Inflorescence.*

It rarely happens that a plant bears only single or very few flowers. An example of such a plant is the tulip. Usually a plant bears blossoms in considerable or large numbers. In many plants they arise in the axils of leaves, either singly or in groups. In the first case the inflorescence is *axillary*, in the latter *whorled* (Fig. 102).

In most plants the blossoms are borne on a special shoot, frequently much branched, which is at once distinguishable from the leaf-bearing stems of the plant by the numerous flowers arising from it. Such a flower-shoot is termed an *inflorescence*. An individual plant may have one, several, or many inflorescences.

Inflorescences are characterised by differences in the size, number, and shape of the flowers composing them, and by the order in which the individual blossoms open. The kind of inflorescence is also determined by their general arrangement and relative positions, which are dependent on the mode of branching. In many even the form of the calyx and corolla are of importance.

Fig. 102.

Whorled inflorescence of white dead-nettle (*Lamium album*), ½ nat. size.

The mode of branching—one of the most essential considerations in the study of inflorescence—is often somewhat difficult to make out. To understand it properly we must first get a clear idea of the difference between the *primary* and *secondary axes* (Fig. 103).

The primary axis is that branch of the inflorescence from which all the other branches spring. It is, therefore, to the inflorescence what the stem is to the plant, forms like the latter the central support, and is usually stronger than any of its ramifications (A, B, Fig. 103).

The *secondary axes* are the branches (*a*) given off by the *primary axis*, which they seldom equal in thickness. Each secondary axis bears one or several flowers. All inflorescences whose secondary axes bear each a solitary flower are said to be *simple;* all those whose secondary axes bear each several or many flowers, are said to be *compound.*

The order in which the flowers open in an inflorescence is another important feature. We may have *the central flowers* opening first, the outermost one last, in which case the central flowers are the oldest, the outermost, the youngest. In Fig. 104 we have an inflorescence of this type; the circles of different sizes represent flowers in different stages of evolution. 1 is the oldest, 8 the youngest. This mode of evolution is termed *centrifugal*, because its progress is from the centre (*A*, *B*) outwards.

The second mode of evolution (Fig. 105) is exactly the opposite

of the one above described. The outermost flowers are the oldest, and open first (1, 2), the central flowers the youngest,

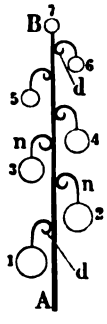


FIG. 103.

Inflorescence.
A B Primary axis,
n Secondary axis,
d Dracts, 1—7 flowers.

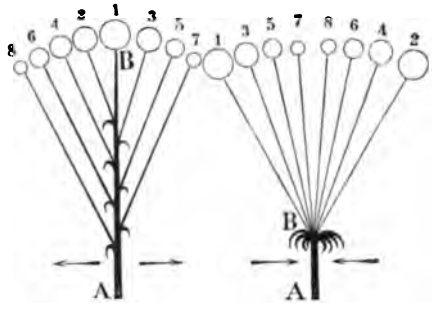


FIG. 104. FIG. 105.

Manner in which inflorescence flowers.
Fig. 104, Centrifugal; 105, Centripetal,

and open last (7, 8). This mode of evolution is termed *centripetal* because its progress is from the margin inwards towards the centre (*A*, *B*). If such inflorescences are long and narrow, the flowers *at the foot* open first, those *at the top* last (Fig. 103).

Let a perpendicular line (|) represent the primary axis (centre) of the inflorescence; an arrow (→) the direction in which the evolution of the flowers proceeds, the *centrifugal* mode will be represented thus ←|→, the *centripetal* thus →|←.

When the primary axis of the inflorescence is very long, *i.e.*, longer and stronger than its branches, it is termed a *raceme* (Fig. 103). In other cases it is of the same length as the secondary axes (Fig. 104), or it may be much shorter (Fig. 105).

Let a point (.) represent a shortened primary axis, then the sign (→·←) will represent a centripetal inflorescence with shortened axis, the sign (←·→) a centrifugal inflorescence with a shortened axis, while →|← represents a centipetal inflorescence with an elongated axis.

According to these points of distinction inflorescences are classed as *racemose, umbellate,* or *cymose.*

I. *Racemose Inflorescence.*—The primary axis is elongated, and is longer and stronger than its branches. The evolution of the flowers is centripetal; the lowest flowers open first, those at

the summit last—sign →|←. The racemose type includes

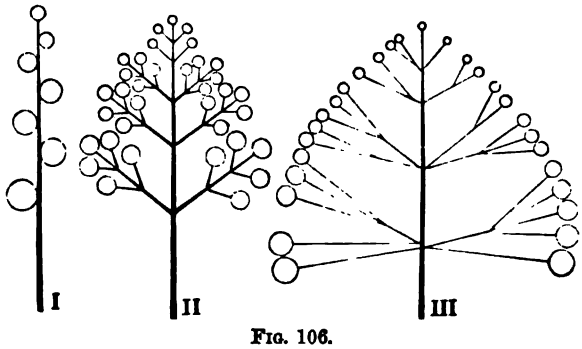


FIG. 106.

Forms of Inflorescence.—I. Spike; II. Compound raceme; III. Panicle.

the *spike*, the *catkin*, the *cone*, the *spadix* (Fig. 103), the *raceme*, and the *panicle*.

II. *Umbellate Inflorescence.*—The primary axis is shortened, and ends suddenly; all the flower-stalks spring from one point; the evolution of the flower is centripetal; the marginal florets open first, the central last—sign →·← The umbellate type includes the *capitulum* or head, the *anthodium*, the *simple* and *compound umbel* (Fig. 107).

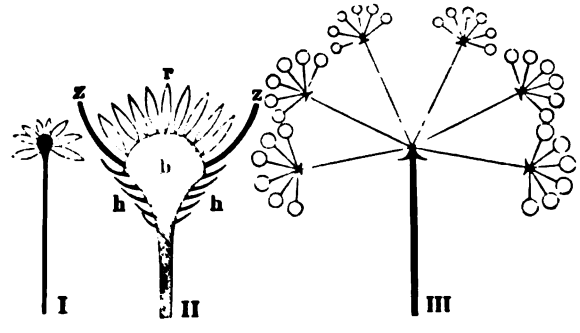


FIG. 107.

Forms of Inflorescence.—I. Anthodium; II. Capitulum; III. Compound umbel.

III. *Cymose Inflorescence.*—Both primary and secondary axes are elongated, the latter being as strongly, or even more strongly, developed than the former. The evolution of the flowers is centrifugal; the central or highest flowers open first, the mar-

ginal or lowest last—sign ⟛. In many only the right or left side of the inflorescence is developed—sign ⊢ or ⊣ The cymose type includes *corymb* and loose corymb,[1] the *dichotomous* or *biparous* cyme, the *compound* dichotomous cyme, the scorpioid cyme, and the helicoid cyme.

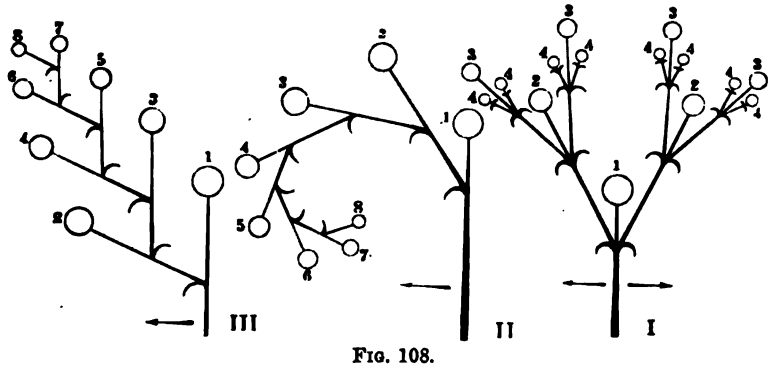


FIG. 108.

Forms of Inflorescence.—I. Dichotomous cyme; II. Scorpioid cyme; III. Helicoid cyme.

Tabular View of the various Forms of Inflorescence.

I. *Racemose Type*—(⟛)

A. Lateral axes unbranched, each bearing only one flower (spike-like form).

a. Flowers sessile on the primary axis; branches wanting or very short.

* Primary axis thin and dry.

1. Flowers loose; not scale-like. . SPIKE.
2. Flowers closely set, forming a cylindrical-shaped head; florets scale-like, ... CATKIN.
3. Flowers closely set, forming a thickish cylinder; each floret with scaly bracts, ... CONE.

** Primary axis thick and fleshy; flowers closely set, ... SPADIX.

b. Flowers on pedicels, ... RACEME.

B. Secondary axes branched, each with several or many flowers (panicled inflorescence).

a. Branching of the secondary axes regular, each bearing a single cluster, ... COMPOUND RACEME.

b. Branching of the secondary axes; irregular, . PANICLE.

[1] English and French botanists do not usually regard the corymb as cymose, but refer it to the racemose type. (*Tr.*)

II. *Umbellate Inflorescence*—(→·←)

A. Secondary axes not branched, each bearing a single flower.

a. Secondary axes shortened; flowers sessile, or with very short stalks.

* Bracts absent or small, . . . ANTHODIUM.

** Bracts, large, numerous, overlapping each other, forming a common involucre, CAPITULUM.

b. Secondary axes *not* shortened; flowers stalked, SIMPLE UMBEL.

B. Secondary axes branched, each bearing one or more simple umbels, ... } COMPOUND UMBEL.

III. *Inflorescences*—(←¦→ *or* ←┤)

A. Inflorescence, branched right and left from the primary axis (in most cases shortened)— ←┼→

a. Secondary axes not branched (each bearing a single flower).

* Flower-stalks (secondary axes) arising from the primary axis at different heights, of unequal length, so that all the flowers lie in one plane, . . CORYMB.[1]

** The same flower-stalks (secondary axes) very unequally developed, so that the shape of the inflorescence is not the same in all cases, ... LOOSE CORYMB.[1]

b. Secondary axes branched (each with several flowers).

* Primary axis terminated by a flower, beneath which two opposite secondary axes arise, each likewise ending in a flower. Primary axis terminated by a flower, beneath which two opposite secondary axes arise, each likewise ending in a flower, beneath which two opposite tertiary axes arise on each fork, each again with terminal flower, &c. } DICHASIUM or "DICHOTOMOUS CYME."

** Secondary axes giving off three, four, or more branches, often irregularly, otherwise like the dichotomous cyme, } COMPOUND DICHOTOMOUS CYME.

B. Secondary axes developed only on one side of the primary axis (either left or right), giving the inflorescence a one-sided appearance. All the secondary axes unite, forming an apparently continuous primary axis (false axis) ←┤

a. False axis, spirally twisted, ... } SCORPOID CYME.

b. False axis, forming a zig-zag line, . . . } HELICOID CYME.

[1] See note on preceding page.

Description of the various Forms of Inflorescence.

(1.) The *Spike* (Fig. 112).—The primary axis is long and slender, often undulating. On its surface are little depressions, from which arise the sessile flowers. The lowermost flowers open first, those at the apex (terminal flowers) last.

EXAMPLES.—The spike occurs chiefly among the grasses (*rye, barley, cat's-tail, foxtail*), but among these the inflorescence is not simple, but compound,—*i.e.*, where we should expect only a single flower we get a small spike or spikelet. In other plants (*oak, mercury*) the florets of the spike form clusters (Fig. 114, I.).

(2.) *The Spadix* (Fig. 46) is a spike with a thick, fleshy axis, the florets set very close together. Between the spike and the spadix we have a type in which the flowers are not arranged so closely as in the spadix, nor so widely apart as in the spike.

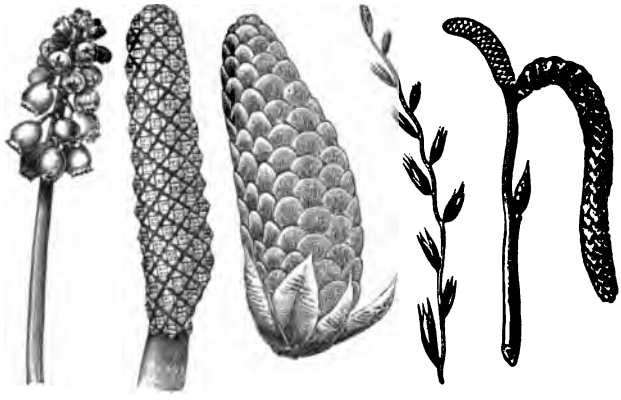


FIG. 109. FIG. 110. FIG. 111. FIG. 112. FIG. 113.

Forms of Inflorescence.—Fig. 109.—Raceme of bell hyacinth (*Muscari racemosum*); nat. size. Fig. 110.—Spadix of pond-weed (*Potamogeton lucens*); nat. size. Fig. 111.—Cone (with ♀ flowers) of the pine (*Pinus sylvestris*); three times enlarged. Fig. 112.—Spike of a grass (*Lolium perenne*); nat. size. Fig. 113.—Catkin (with ♂ flowers) of the birch (*Betula alba*); nat. size.

EXAMPLES.—Arum, lily of the Nile (*Richardia africana*), pondweed (*Potamogeton*).

(3.) *The Catkin* (Fig. 113) is a spike with slender axis and small, green, close-set flowers. The flowers are concealed by large scaly bracts, which lie so flat and close together as to give the catkin a cylindrical shape. The catkin separates as a whole from the plant when withered, the ♂ after the flowers are past,

the ♀ after the fruit is ripe. The spike again does not separate as a whole, but the individual florets drop off, leaving the axis behind.

EXAMPLES.—Catkins are found on many trees (catkin-bearers)—hazel, walnut, poplar, willow, alder, aspen, beech, birch.

(4.) *The Cone* (Fig. 111) is a catkin, whose scaly bracts become woody when the fruit is ripe. It is rounded and elongated in shape. When ripe the individual flowers or fruits do not drop off, but the inflorescence falls as a whole, as in the case of the catkin.

EXAMPLES.—The cone is the characteristic inflorescence of the pines (fir, larch, pine), whence they are termed *coniferæ* or cone-bearers.

(5.) *The Raceme* (Fig. 109) is a spike with stalked flowers. The lowermost flowers open first, the uppermost last. The raceme may be either erect or drooping.

FIG. 114.

Types of Inflorescence.—I. Spike of mercury (*Mercurialis annua*); II. Panicle of brome-grass (*Bromus mollis*); III. Capitulum or head of clover (*Trifolium pratense*); nat. size.

EXAMPLES.—Inflorescence racemose—hyacinth, lily of the valley, barberry, foxglove, harebell, heath.

(6.) *The Panicle* (Fig. 114, II.) is a raceme with irregularly branching secondary axes. The lowest (sometimes also branched) are the longest, further up they are shorter. The shape of the panicle is irregular.

EXAMPLES. — Many grasses have their flowers in panicles—sedge, oats, quaking-grass, brome-grass.

(7.) *The Capitulum or Head* (Fig. 114, III.).—The primary axis terminates suddenly, and bears at its summit a large number of close-set sessile or very short-stalked flowers, forming a ball-shaped head.

EXAMPLES.—*Capitula*—clover, mountain jasione, scabious, devil's bit scabious.

(8.) *The Anthodium* (Fig. 115) resembles the capitulum. The primary axis ends suddenly, and widens out into a convex disc, the receptacle on which the sessile florets are inserted. In many cases the florets are of two kinds, ligulate at the circumference (ray-florets, *z*, Fig. 107, II., Fig. 85), tubular centrally (disc florets, *r*, Fig. 107, II.). At the base of the anthodium are a number of bracts, which overlap each other, forming an *involucre* (*h*).

EXAMPLES.—The anthodium is the characteristic inflorescence of the Compositæ. Examples of flowers having an anthodium entirely composed of ligulate florets are — dandelion, goat's - beard, chicory, lettuce; flowers with anthodium composed of tubular as well as ligulate florets are—sunflower, daisy, camomile, corn-marigold.

FIG. 115.
Anthodium of thistle (*Cirsium oleraceum*); nat. size.

(9.) *The Simple Umbel* (Fig. 116) is like the capitulum, only its florets are borne on long stalks. All the florets stand at the same level, at least by the time all are full blown. At the spot where the secondary axes arise from the stem is a rosette of bracts forming an *involucre*.

EXAMPLES.—*Simple umbel*—Primrose, sanicle, pennywort (*Hydrocotyle*).

(10.) *The Compound Umbel* (Fig. 117) differs from the simple umbel in this, that instead of bearing a single terminal flower, each secondary axis bears a secondary umbel, which, like the simple umbel, is surrounded at its base by an involucre.

EXAMPLES.—The compound umbel is the characteristic inflorescence

of the Umbelliferae—water hemlock, fool's parsley, carrot, chervil, celery, caraway.

FIG. 116.

Simple umbel of the oxlip (*Primula elatior*); nat. size. *h* Involucre.

FIG. 117.

Compound umbel of the water-hemlock (*Cicuta virosa*); half nat. size.

(11.) *The Corymb* (Fig. 104) is an inflorescence having the primary axis suddenly shortened. The secondary axes each bear one flower; arise, as in the raceme, at different levels; but end, as in the umbel, at the same level. There is a single

FIG. 118.

Corymb of the rush (*Juncus effusus*); nat. size. *a* Culm, *b* Bract.

FIG. 119.

Corymb (of anthodia) of milfoil (*Achillea millefolium*); nat. size.

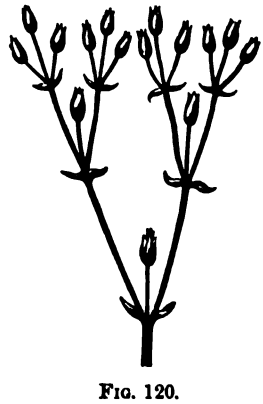


FIG. 120.

Dichasium of chickweed (*Stellaria media*); nat. size.

bract in connection with each flower, and no involucre as in the umbel. The corymb of the rush is exceedingly irregular, probably a degenerate cyme (Fig. 118).

EXAMPLES.—*Corymb* (of anthodia)—tansy, milfoil, corn-marigold.

(12.) *The "Dichotomous Cyme"* or *Dichasium* (Fig. 120) is one of the most regular forms of inflorescence. The primary axis terminates suddenly in a flower; beneath this flower arise two secondary axes; each of these branches similarly ends in a flower, and gives off two tertiary axes, and so on (thus producing a superficial resemblance to true dichotomy).

EXAMPLES.—Most of the pink order—(chickweed, &c.).

(13.) *The Compound Dichasium* (Fig. 119) is very similar to the simple dichasium. From beneath the terminal flower of the primary axis spring, not two, but several secondary axes, *e.g.*, three, four. Each of the secondary axes terminates in a single flower, from under which again arise a number of branches, and so on.

EXAMPLES.—*Compound dichasium*—elder, valerian, wild euphorbia. It is not unusual to find the terminal flowers suppressed.

(14.) *The Scorpioid Cyme* is a one-sided inflorescence. We may suppose it to be developed from the dichasium in the following manner (comp. Fig. 108, I. II.). The primary axis is terminated by the flower 1; from beneath this one branch is given off, say, to the left (in the dichasium two are given off at the same spot, one to the left, the other to the right); this secondary axis is terminated by the flower 2, from beneath which another branch (3) is given off to the left, and so on. This one-sided mode of branching gives rise to a one-sided inflorescence; the numerous branches together form a scorpioid axis, closely curled at the tip. The *Helicoid Cyme* (Fig. 108, III.) is a similar one-sided inflorescence. It, too, is a development of the dichasium. As in the scorpioid cyme, a simple lateral branch is given off from the primary axis, say, to the left; from this one is given off to the right, from this one to the left, and so on, left and right lateral branches always alternating. A zigzag false axis is thus formed.

FIG. 121.

Double scorpioid cyme of the marsh forget-me-not (*Myosotis palustris*); nat. size.

Note.—The scorpioid and the helicoid cyme often closely resemble the spike and the raceme; they may be distinguished as follows:—In the spike and raceme the floret and the bract belonging to it are to

be found on the same side of the axis, in the scorpioid and helicoid cyme the floret is found on one side of the false axis (*e.g.*, the right), the bract on the other (*e.g.*, the left) (comp. Fig. 103 with 108, III.).

EXAMPLES.—The helicoid cyme is rare; examples are found in the day-lily and the perforated St. John's wort. The scorpioid cyme is characteristic of the borage family (*e.g.*, forget-me-not, heliotrope).

The forms of inflorescence are of importance with regard to the classification of plants. Large groups of plants are thus classified, *e.g.*, the Catkin-bearers (catkins), the Coniferæ (cones), the Umbelliferæ (compound umbels), the Compositæ (anthodia). Further, we find a certain form of inflorescence to be characteristic among most of the plants of a class, even although it is not made the ground of classification—grasses (spike and panicle), the pinks (dichasium) rushes (irregular corymb), borages (scorpioid cyme).

Sometimes we find a combination of two modes of branching in one inflorescence. In the panicle, *e.g.*, the branches almost always bear spikes (Fig. 114, II.); the corymb, instead of having a single terminal floret on each of its branches, may have an anthodium (Fig. 119), &c.

6.—*The Fruit.*

It has already been said that the organs of the flower, after they have attained a certain age, wither and fall off. To this general statement the ovary forms an exception; after the other parts of the flower have faded, the ovary enlarges and finally develops into what is familiar to us as the fruit. The fruit consists of a hard or fleshy envelope, containing one or more cavities or "cells." Adhering to the walls, or attached to short stalks, we find the seeds enclosed in these spaces. In the seed is the germ of the new plant; we all know that when it is sown in the soil a young plant is developed from it. *Reproduction of plants is effected by means of the seed.*

The ovary only develops into the fruit, and the ovules into seed, if during the period of flowering pollen has had access to the stigma. More will be said of this hereafter.

When a flower contains only one ovary, there will be only one fruit; *e.g.*, we only get one cherry from a single cherry blossom. In those fruits again which have several or many ovaries, we find several or many fruits; in fact just as many as there were ovaries. As in this case the fruits lie close together so as to form a cluster, the fruit taken as a whole is termed *aggregate.*

EXAMPLES.—The best known aggregate fruits are raspberry and bramble. They are formed of a number of small individual fruits,

crowded together in one mass, each somewhat rounded in shape, not unlike a plum.

In certain instances the ovary alone does not constitute the fruit, but other organs of the flower take part in its composition. Two well-known instances are the rose and the strawberry. The *hip* is the name we give to the fruit of the rose; it consists of a red, fleshy envelope, inside of which we find a number of hard, elongated, hairy seeds. The red envelope is not, as we might suppose, the swollen pistil, but the end of the axis, which has become enlarged, cup-shaped, and rather fleshy; the seeming seeds are not merely seeds, but *fruits*. In the strawberry the red succulent part is formed by the axis or *receptacle;* the little seed-like bodies which dot its surface are the fruit. The pseudo-carpous fruit of the rose and strawberry are at the same time aggregate.

Pericarp is the general name for that part of the fruit which is not the seed. The pericarp may be thick or thin, fleshy (succulent), or dry. Sometimes we can distinguish in it several layers, which are then called the external, internal, and middle pericarps, or *epi-*, *endo-*, and *mesocarp* respectively. These three layers are well seen in the plum. Here the external pericarp is the thin, purplish, rather bitter skin which covers the surface of the plum; under this lies the greenish yellow, succulent mesocarp (the flesh), and within this is the internal pericarp. The last is very hard and woody, and contains a single seed. We call it the *stone* of the fruit.

When the fruit is ripe, *i.e.*, fully developed, it in many cases falls to the ground. In others it splits up into separate parts, and these fall singly. Other fruits again burst open and scatter the seed abroad, while the husk remains hanging on the plant.

EXAMPLES.—*Fruits which remain entire*—cherry, plum, apple, bilberry, cocoa-nut. *Fruits which split into parts*—carrot, caraway, maple. *Fruits from which seed is scattered*—poppy, rape-seed, pink, laburnum, thorn apple.

Fruits vary much in the number of seeds which they contain. Some have but one, others two or three, others many.

The *external appearance* and *character* of the fruit depend on the character of the pericarp. Fruits are distinguished by the manner in which they open, the number of seeds, the number of cells, and so on.

According to the character of the pericarp, all seeds are divided into *dry*, and *succulent* or *fleshy*, and these (according as they open or not when ripe) may be *dehiscent* or *indehiscent*.

I. *Dry Fruits.*—The pericarp is thick and leathery, never soft and juicy. Dry fruits include the *grain*, the *nut*, the *winged nut*, the *samara* or *winged fruit*, the *cremocarp*, the *schizocarp*, the *siliqua*, the *legume*, the *capsule*.

II. *Succulent Fruits.*—When ripe the pericarp is altogether or partly soft and succulent, often very juicy. Succulent fruits include the *drupe*, the *berry*, the *pepo* or gourd-fruit, the *pome*, the *soft capsule*, and the *walnut*.

Tabular View of the various Kinds of Fruit.

I. *Dry Fruits.*

A. Indehiscent, one or two seeded (nuts, &c.).
  a. One-seeded.
    * Wingless.
      1. Pericarp, thin and leathery, seed adherent, — GRAIN.
      2. Pericarp, thick, hard, and woody, easily separated from the seed, . . . — NUT.
    ** *Winged*, ... — WINGED NUT.
  b. Two-seeded. When ripe splitting into two halves, held together by a stalk.
    * Winged, ... — SAMARA.
    ** Wingless, ... — CREMOCARP.

B. *Dehiscent;* mostly with several seeds (dry dehiscent fruits, capsules).
  a. Simple, dry, dehiscent fruits (formed by one carpel), one-celled, seeds one or more.
    * Opening along one suture; seeds one or more; mostly aggregate, ... — SCHIZOCARP.
    ** Dehiscing along two sutures, always with several seeds, never aggregate, . . . — LEGUME.
  b. Compound dry dehiscent fruits (composed of two or more carpels), cells one or several, seeds always numerous.
    * Elongated, composed of two carpels, two-celled (with partition), seeds adherent to the two margins of ventral suture, dehiscing along both sutures, ... — SILIQUA.
    ** Rounded, composed of several carpels (*e.g.*, five, ten), dehiscing by pores or by a lid, . — CAPSULE.

II. *Succulent Fruits.*

A. Succulent indehiscent fruits. The seed or seeds surrounded by a succulent pericarp, which becomes juicy when ripe.
  a. One-celled.

II. *Succulent Fruits*—continued.

* One-seeded; seed with woody inner pericarp (stone), ... DRUPE.
** Usually with several seeds; no woody inner pericarp.
1. Fruit containing few seeds, usually attached to the centre, . . . BERRY.
2. Fruit, many-seeded, seed attached to dissepiments in crossing centre, . PEPO OR GOURD FRUIT.
b. Several-celled, ... POME.
B. Succulent dehiscent fruits:—
Pericarp soft, but not juicy.
a. Several seeded, ... SOFT CAPSULE.
b. One-seeded, ... WALNUT.

Description of the various Fruits.

(1.) *The Grain* (Fig. 122) is indehiscent, and has a dry leathery pericarp, containing one seed, to which it is adherent; the pericarp, therefore, cannot easily be separated from the seed.

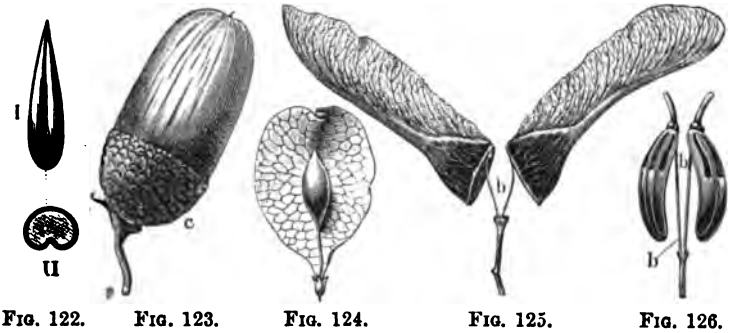


FIG. 122. FIG. 123. FIG. 124. FIG. 125. FIG. 126.

Fruits.—Fig. 122.—*Grain* of the oat (*Avena sativa*); II. Cross section of the same. Fig. 123.—*Nut* of the oak (acorn). Fig. 124.—Winged nut of elm (*Ulmus campestris*). Fig. 125.—*Samara* of maple (*Acer platanoides*). Fig. 126.—*Cremocarp* of *Heracleum sphondylium*; nat. size. *b* Stalk, *c* Cupule.

EXAMPLES.—The grain is the characteristic form of the fruit of grasses and the Compositæ. *Caryopsis* is the term which applies more especially to the grasses. *Achene* is the name given to the fruit of Compositæ. Examples of the *caryopsis* are rye, wheat, barley, oats, millet, maize, rice, &c.; of the *achene*—daisy, dandelion, thistle, sunflower, &c. The caryopsis is to be distinguished from the achene by its inseparable pericarp and by its being channelled externally in the long direction.

(2.) *The Nut* (Fig. 123) is likewise a dry, one-seeded, indehiscent fruit. Its pericarp is thick, leathery, or wood, and not

adherent to the fruit, so that the latter remains intact after the shell is broken. Sometimes, but not always, the lower end of the nut is surrounded by a kind of involucre called the *cupule* (*c*, Fig. 123).

EXAMPLES.—Hazel-nut, acorn, cocoa-nut (but not the walnut).

(3.) *The Winged Nut* (Fig. 124) is a dry, one-seeded, indehiscent fruit, the tough pericarp of which is extended so as to form a broad flat rim around the fruit, which serves the latter as wings.

EXAMPLES.—Birch, elm, ash.

(4.) *The Samara* or *Winged Fruit* (Fig. 125) differs from the winged nut in having two seeds. When ripe, it splits into two halves, each winged, but still held together by a thin, divided stalk. After a time these usually fall away singly.

EXAMPLE.—The samara is characteristic of the maples.

(5.) *The Cremocarp* (Fig. 126) is similar to the samara, but is wingless. When ripe it splits into two halves, which fall singly, and are ridged or prickly externally.

EXAMPLES.—All Umbelliferæ (caraway, hemlock, parsley, fennel, chervil, cow-parsnip, &c.).

(6.) *The Schizocarp* (Fig. 97, III., VIII., X) is a dry, dehiscent, always simple fruit, composed of one carpel. It may have one or several seeds. If several, they are attached to the suture, forming one row. Dehiscence takes place along the suture. Schizocarps are mostly aggregate.

EXAMPLES.—Anemone, meadow rue, liver-wort, arrowhead.

Note.—The shade-loving herb-Christopher or baneberry (*Actæa spicata*) has its fruit in the form of a dark blue fleshy schizocarp, which causes it frequently to be mistaken for a berry.

(7.) *The Legume* (Fig. 127) is a dry, dehiscent, simple fruit, composed of one carpel. It has several seeds placed in a row. It dehisces by two sutures. Legumes are never aggregate; each flower produces only one. The legume is long and narrow in shape.

EXAMPLES.—All papilionaceous flowers have fruit in form of a legume, *e.g.*, lupin, laburnum, beans, lentil, pea, vetch. In the fruit of the bladder-senna (*Colutea arborescens*) the pericarp is inflated like a bladder; the fruit may be said to be a bladder-like legume.

Note.—The term *lomentum* is applied to a certain form of legume which is constricted into joints, this giving it a beaded appearance. At each constriction there is a dissepiment, so that the pod is divided into as many cells as there are expansions. The lomentum does not burst open along its length, but falls to pieces by dividing at the dissepiments (*e.g.*, *Ornithopus*).

The Siliqua (Figs. 128, 129) is a dry, dehiscent fruit, formed by two carpels, and having two cells in valves. It is many-seeded; the seeds are arranged in two rows.

It dehisces by two sutures from below upwards, or *vice versa*, the central membranaceous dissepiment remaining attached to the stalk.

According as the partition is broad or narrow, the siliqua is termed *latiseptate* or *angustiseptate*. A very short siliqua (Fig. 128) is called a *silicula*.

EXAMPLES.—The siliqua is the characteristic fruit of the *cruciferæ;* wallflower, wild mustard, cress, penny-cress, shepherd's purse, whitlow-grass, watercress.

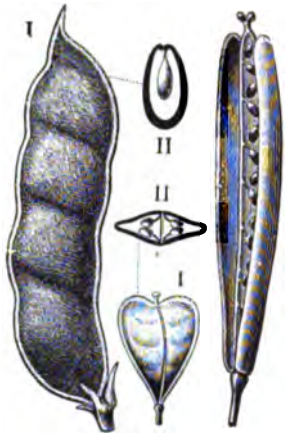


FIG. 127. FIG. 128. FIG. 129.

Fruits.—Fig. 127. I.—Legume of lupin (*Lupinus multiflorus*) —nat. size; II. The same in cross section. Fig. 128.—Siliqua of shepherd's purse (*Capsella bursa pastoris*); three times enlarged. II. Cross section. Fig. 129.—Siliqua of *Matthiola incana;* nat. size.

(9.) *The Capsule* (Figs. 130, 131) is a dry dehiscent fruit, com-

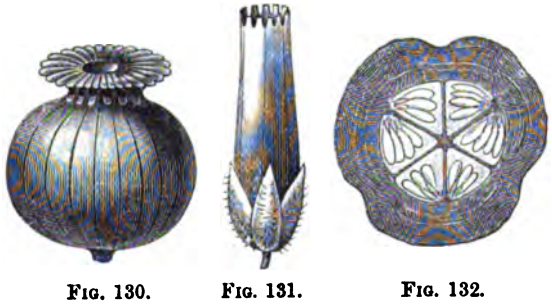


FIG. 130. FIG. 131. FIG. 132.

Fruits.—Fig. 130.—Capsule of poppy (*Papaver somniferum*); nat. size. Fig. 131.—Empty capsule of chickweed (*Stellaria media*); six times nat. size. Fig. 132.—Cross section of cucumber (*Cucumis sativus*); nat. size.

posed of several carpels. It is easily distinguished by its shape from such forms as the siliqua and legume; it is rounded or

very slightly elongated, never long, narrow, and flattened like those forms of fruit. It is many-seeded, never one-seeded.

The number of carpels constituting the pericarp varies. Usually there are ten or five carpels, but sometimes, as in the Lychnis tribe, which almost all have capsules, we get besides five and ten, six, four, or three carpels. Capsules composed of two carpels are not uncommon, *e.g.*, in the *Personatæ*. The seeds are either attached to the walls of the capsule, or to a central column. The dehiscence is either by *valves*, *pores*, or a *lid*.

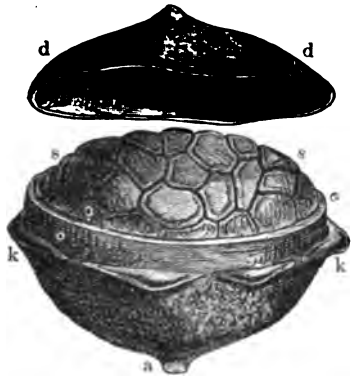


FIG. 133.

Pyxis of "monkey-pot" (*Lecythis ollaria*). *a* Stalk, *k k* Withered leaves of persistent calyx, *e* Spot where capsule opens, *d d* Lid, *s s* Seed adhering to internal surface of capsule. Their peculiar irregular shape is due to the pressure they have undergone during development.

(*a.*) *Valvular Dehiscence* (Fig. 131).—This species of dehiscence takes place in the long direction. The carpels usually separate along their sutures. The capsule begins to open at the end nearest the stalk, and the dehiscence ends at the top, where we usually find as many teeth as there are carpels in the capsule.

(*b.*) *Porous Dehiscence* (Fig. 130).—When the fruit is ripe, openings or pores form in the sides of the capsule, through which the seeds fall out.

(*c.*) *Transverse* or *Circular Dehiscence* (Fig. 133).—A groove is formed round the circumference of the capsule (*e*, Fig. 133), along which the upper part of the capsule separates from the lower. The upper part is called the lid; it falls off, and the seed is set free. This form of capsule is called a *pyxis* or *pyxidium* (Gr. *pyxis*, a box).

EXAMPLES.—*Valvular capsules*—pink, cuckoo pink, corn-cockle; *porous capsules*—poppy, blue-bell; *Pyxidia*—pimpernel, monkey-pot (Fig. 133).

(10.) *The Drupe* is a juicy, simple, one-seeded, indehiscent fruit. The pericarp is divided into three layers—external skin-like, middle fleshy, and internal woody. The woody pericarp contains the softish seed, which lies free in the inside. The woody pericarp and seed together form the stone (plum, cherry, &c.).

EXAMPLES.—All the "stone fruits" are *drupes*—peach, apricot, plum, sloe, cherry, damson.

(11.) *The Berry* is a juicy, usually simple and several-seeded, indehiscent fruit. The pericarp is in two layers—an outer skin-like, and an inner succulent layer. The seeds do not lie in a woody layer of the pericarp, their attachment is usually central, occasionally parietal (gooseberry).

EXAMPLES.—Bilberry, laurel, grape, gooseberry, currant, snowberry.

(12.) *The Pepo* or *Gourd-Fruit* (Fig. 132) is, properly speaking, a large berry with a thick pericarp. It contains a large number of seeds which are attached to partition-like placentæ. When ripe it contains, like the berry, a large quantity of juice.

EXAMPLES.—Pumpkin, cucumber, melon.

Note.—Fruits of the orange species (orange, citron, lemon) are also to be regarded as a variety of berry. They are multicellular, and each cell is filled with pulp, which surrounds the seed.

(13.) *The Pome* is a succulent, several-celled, several-seeded, indehiscent fruit. The pericarp consists of three layers—an external skin-like, a middle fleshy, and an inner parchment-like layer, which forms the cells. Usually there are five cells. If the seeds are woody and hard the pome is said to be *drupaceous*.

EXAMPLES.—Apple, pear, quince; *drupaceous*—hawthorn, medlar.

(14.) *Fleshy Dehiscent Fruits* are rare, and require no peculiar names. Their pericarp is fleshy, but not juicy.

Such a fruit is, *e.g.*, the *walnut*. Its seed is surrounded by the woody inner layer of the pericarp. The outer layer is fleshy, very unpleasant to the taste, and of a green colour; it opens when the fruit is ripe. The walnut may therefore be compared to a dehiscent stone fruit.

The horse-chestnut is an example of a *fleshy capsule*. At first it is two-celled and six-seeded, but in development it becomes three-valved and two-seeded; the green prickly and fleshy pericarp opens when ripe, and the two large seeds fall out.

The fruit of the balsam may be most conveniently compared to a fleshy siliqua. On account of its peculiar mode of dehiscence this plant is called touch-me-not (*Impatiens noli-me-tangere*). If the ripe capsules of the balsam are touched they open at once, the fleshy valves curl themselves up like a watch-spring, and the seeds are scattered by the sudden movement.

We already know that plants may be arranged according to their mode of inflorescence. They may also be arranged according to the

form of their fruit. Thus the grasses have a caryopsis, the *Compositæ* an achene, the maples a samara; similarly a cremocarp characterises the Umbelliferæ, a schizocarp the Ranunculaceæ, a legume the Papilionaceæ, a siliqua the Cruciferæ, a capsule the poppy, pink, primrose, blue-bell, lily, iris, orchis, violet; a drupe the almond, a berry the bilberries, a pome the apple, a pepo the pumpkins, and so on.

C.—The Seed.

In the young ovary are found, as we have already seen, the *ovules.* While the ovary is developing into the fruit, the ovules are developing into the seed. The fruit may contain one, several, or many seeds.

The essential parts of the seed are the *embryo,* from which the young plant is developed, and the *seed-coat* or integument, which covers the embryo and protects it from injury (Fig. 21). Besides these two parts, there is found in many seeds a homogeneous white, grey, or yellowish-looking mass, which may be either floury, fleshy, hard, or tough, and which serves as a store of nourishment for the young plant during the early stages of growth. This mass is the *albumen.*

Examples.—*Well-known examples of exalbuminous seeds* (seeds without albumen) are the bean, pea, lentil, &c.; *seeds containing a large quantity of albumen* are, *e.g.*, those of the grasses, or the nut of *Phytelephas macrocarpa,* in which the albumen is so hard that it can be worked like ivory.

Fig. 134.

Longitudinal section of grass seed. *f* Plumule, *w* Radicle, *s* Seed-coat (diagrammatic).

The arrangement of embryo and albumen in the seed is seen in Fig. 134, where we have a longitudinal section of a grass seed much enlarged. The surface of the seed is covered by a strong integument, the *seed-coat* (*s*) which in this case is yellowish in colour. At the base of the seed is the *germ* or *embryo* (Gr. *embruon,* a seed), which is again made up of several parts. The upper prominence is the germ into that part of the plant which appears above the ground, the lower (*w*) is the germ of the root. The former (*f*) is called the *plumule,* the latter (*w*) the *radicle.* Beside the plumule, but more towards the centre of the seed, is a rather long, narrow leaflet, which, when the seed sprouts, is the first to appear above the ground and

assume a green colour. As this leaf is already formed in the seed it is called the seed-leaf or cotyledon. Close to the embryo is the large floury mass of albumen (*e*), which forms the earliest nutriment of the young seedling.

In cases where the albumen is awanting the nutriment is stored in the cotyledons themselves. We have already seen the seed of the bean (Fig. 21). In it we find the germ of the future plant (*e*) enclosed in the strong white seed-coat (*f*, II.) and two cotyledons (*e e*), which are thick and fleshy, and loaded with nutritive material.

By the examination of the grass seed and of the bean, we learn that some seeds have two cotyledons, others only one.

IV.—HAIRS, &c.

Hair structures are not, like flowers and leaves, confined to a certain part of the plant, but are to be found on root, stem, and leaf structures.

They are usually small and fine, and therefore run a greater risk of being overlooked in a superficial scrutiny. Hair structures are found only on the surface of organs, to which they give a velvety, woolly, or rough appearance. Hairs are either cylindrical and pointed, or they are cylindrical with a knob-like head (Fig. 135).

There are always hairs on the surface of roots (*root-hairs*). The extreme ramifications of the rootlets are usually quite covered with them. The shape of these hairs is cylindrical; glandular hairs never occur on roots.

FIG. 135. FIG. 136.

Fig. 135.—Sepal of *Cerastium hemidecandrum*, with cylindrical and glandular hairs; six times enlarged. Fig. 136.—Prickles of the rose (*Rosa centifolia*); nat. size.

The absorption of water from the ground by roots, already spoken of, is mainly accomplished by the root-hairs. These can penetrate the smallest interstices, the spaces between grains of sand, &c., and attach themselves to the smallest particles with great firmness, the plant

being thus very closely connected with the ground. The water penetrates the delicate colourless walls of the hairs, gets into the roots, and is by them conveyed to the other parts of the plant. See Part IV.

The stem and leaves also abound with hairs; if entirely without them, they are said to be naked. Hairs on the stem and leaves either serve to protect these organs against cold, &c., or against the approach of animals, or they may serve as a means of transport for the fruit.

Many plants indigenous to lofty mountains or the polar regions are so thickly covered with woolly hairs that their form is almost concealed. In such cases the hairs are to the plants what fur is to animals. Plants which grow in the desert are often for similar reasons well protected by hairs.

A well-known form of defensive hair is that of the nettle. The pain which ensues upon touching this plant is due to the fact that the surfaces of the leaves are covered with long fine hairs, which contain a poisonous fluid. The walls of these *stings* are hard and brittle, like glass; when the hand comes in contact the sharp points pierce the skin and there break off, upon which a small quantity of the poison is emitted. It is this which causes the burning, itching sensation, which fortunately soon passes off. The same effects are caused by the sting of many exotics. The fruit of *Mucuna pruriens*, a papilionaceous plant common in the Moluccas, is covered with stiff straight hairs; if these are touched they enter the skin, break off, and cause a severe, almost intolerable, itching and burning sensation.

Almost without exception flowers bear hairs on one part or another, which either play a part in connection with insect fertilisation, or protect the flower against damp, and the aggressive attacks of animals. Of this we shall hear more in Part III. The fruit and seeds of many plants are frequently very hairy. The hairs may serve as wings, and admit of the seeds being carried by the wind, so that plants possessing such seeds have a good chance of being widely spread. This, too, will be further considered in Part III.

We usually apply the term *hair* to superficial appendages of the plant, when they are thin, delicate, and flexible. Stiff hairs are termed *bristles*, strong and woody hairs become *prickles* (Fig. 136).

The most familiar examples of woody hairs or prickles are those of the rose and bramble. They are confined to the stem and to the veins of the leaf. If we peel off the rind of a prickly stem, the prickles come away along with it. Prickles are thus easily

distinguished from thorns (Fig. 18). The thorn is a modified branch, covered with a thickish rind, while the prickle is a modification of the epidermis. The distinction between prickles and thorns should be carefully kept in view. In like manner we must guard against confounding the true thorn with thorns which are modifications of leaves (leaf thorns, Fig. 43). The external resemblance between prickles, thorns, and leaf thorns arises from the fact that during the life of the plant they all perform similar functions; they ward off, with their sharp points, the attacks of predatory animals. This function they all perform in the same way, yet the first are hair-structures, the second stem-structures, the third leaf-structures.

PART II.

SYSTEMATIC BOTANY.

Floral Diagrams.

Essentially the flower is composed, as we already know, of three parts, the floral envelopes (calyx and corolla), stamens, and pistil. The calyx surrounds the flower externally, next comes the corolla, next the stamens, and last of all the ovary or pistil.

If we look at a typical flower from above (Fig. 137, I.) we at once see that the centre of the ovary is exactly the central point of the flower; that is to say, if we draw from the points *a*, *b*, *d*, *e*, *f*, the extremities of the petals, straight lines to the point *c*, the lines *c a*, *c b*, *c d*, *c e*, *c f* will all be equal. They are the radii of a circle, which passes peripherally through the points *a*, *b*, *d*, *e*, *f*, and whose centre is *c*.

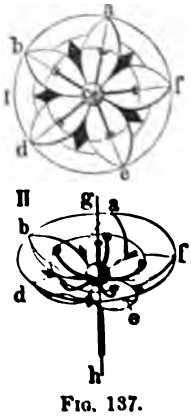


Fig. 137.

Diagram of a regular flower. I. Viewed from above; II. From the side.

It is easy to see that not only can a circle be drawn so as to touch all the extremities of the petals, but other circles can also be drawn which shall touch peripherally the extremities of the stamens and sepals, they being likewise equidistant from the centre (Fig. 137, I.). We therefore speak of a circle of petals, a circle of sepals, and a circle of stamens. Technically these circles are called whorls.

If through the point *c* (Fig. 137, I.) a line is drawn perpendicular to the surface of the flower, it will pass through the centre of the ovary and be continued in the stalk (*g h*, Fig. 137, II.) This will represent the *axis* of the flower.

The Floral Diagram.—If a section of a flower is made in a direction at right angles to the axis (*i.e.*, a *transverse* section), we

find, at least in the bud, the corolla inside the calyx, the stamens inside the corolla, and, in the centre of all, the ovary.

In Fig. 138, I. we have a bud of mock orange blossom (*Philadelphus coronarius*), whose axis lies in the vertical line *A*. If with a sharp knife we make a section through the bud at *B*, at right angles to *A*, we see what is represented in Fig. 138, II. Externally the bud is surrounded by four thick, narrow, green sepals (*k*); then come four white petals (*b*) overlapping each other (black in the figure for the sake of clearness), then a large number of young stamens (*s*), their anthers cut across, and finally the four styles (*f*), their stigmas cut away. This section gives us a very good idea of the more apparent parts of the flower, but as yet we know nothing of its ovary. To discover its structure, we must make a second section through *C* (Fig. 138, I.), also at right angles to the Axis *A*, and therefore parallel to *B*. We shall then see what is represented in Fig. 138, III.: the ovary is four-celled; in each cell are two placentæ, with numerous ovules.

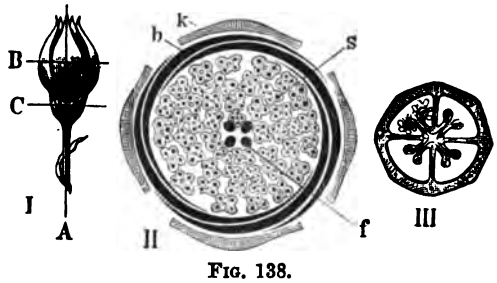


FIG. 138.

Mock orange blossom (*Philadelphus coronarius*).—I. Bud, nat. size; II. section of the same through *B*; III. section through *C*. *A* Axis; *k* Calyx; *b* Petals; *s* Stamens; *f*. Style. (II. and III. four times enlarged.)

If we now make a drawing of what we see when we lay the two sections one on the top of the other, in such a way that their centres correspond, we shall get the Figure 139. In this diagram we have a representation of *all* the more important parts of the flower, as if they lay in one plane.

A section of this sort is termed a *floral diagram*.

There are but few plants in which we can see all the parts of the flower and their mutual relationships in a single section. We have an example of this, however, in the tulip (*Tulipa Gesneriana*). If we make a section through the flower about half-way up, we shall find that it passes through the six parts of the perianth, the stamens, and the ovary. The single section gives us the complete floral diagram. Whereas in this case we find that the floral diagram is simply a somewhat diagrammatic representation of the transverse section, we must remember that it is possible to have many varieties, differing from

this in being either simpler or more complicated. We may concentrate on the more general relations of part to part, and thus obtain a diagram simple, clear, and capable of being understood at a glance; or we may attempt to delineate the more minute features of structure and relationship, and thus obtain a diagram less easy to understand, but more exact as to particulars. In any case, the diagram is the simplest possible expression of the characteristic peculiarities of the flower, and, given only a knowledge of the rules regulating its construction, any one can easily represent thereby the structure of any flower which may fall under his consideration. Moreover, it is only by familiarity with the art of diagrammatic representation that one can hope to obtain a full and clear idea of the characteristics of the groups into which plants are divided, and of the relationships which exist between one group and another. We shall now proceed first of all to study the rules which govern the construction of the diagram, and to consider the various forms which it may assume, after which it will be possible for us to take a general view of the leading natural orders. We shall begin with the very simplest forms, and pass upwards to the more complex, until we arrive at those which show us all the most important relations which exist between the parts of the flower.

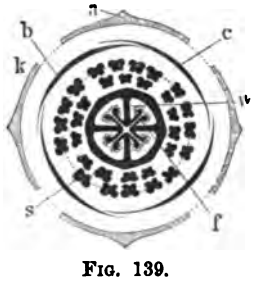


FIG. 139.

Floral diagram of mock orange blossom (*Philadelphus coronarius*). *a k* Calyx, *b c* Petals, *s* Stamens, *f* Ovary, *w* Dissepiments.

Construction of the Floral Diagram.

Usually the floral diagram consists of five concentric circles (Fig. 140). On the first (1) lie the sepals of the *calyx* (calyx-

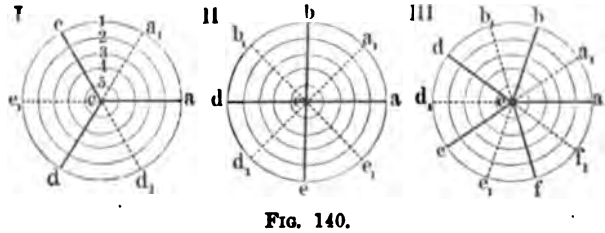


FIG. 140.

Outlines for construction of floral diagrams.

circle), on the second the petals of the *corolla* (corolla-circle), on the third and fourth (3, 4) the *stamens* (stamen-circle) on the innermost (5) the *ovary* (ovary-circle). The number of parts forming each circle may always be traced back to the following *fundamental types*:—

(1.) *The Three-leaved Type* (*trimerous*).—Flowers with three sepals, three petals, 2 × 3 stamens, and three-celled ovary.

(2.) *The Four-leaved Type* (*tetramerous*).—Flowers with four sepals, four petals, 2 × 4 stamens, a four-celled ovary.

(3.) *The Five-leaved Type* (*pentamerous.*)—Flowers with five sepals, five petals, 2 × 5 stamens, a five-celled ovary.

Corresponding to these floral types we have *trimerous, tetramerous, pentamerous floral diagrams.*

To construct a *trimerous* diagram, draw, first, five concentric circles (Fig. 140, I.), divide the outermost into six equal parts, and connect the points $a\ a^1\ e\ e^1\ d\ d^1$ in its circumference with the centre (c) by means of straight lines; $a\ c$, $e\ c$, and $d\ c$ may be drawn in as *dark*, $a^1\ c$, $e^1\ c$, and $d^1\ c$ as *dotted* lines. The dark lines are the *radii*, the dotted lines the *inter-radii.* The trimerous diagram has *three radii* and *three inter-radii.* Now draw in (as in Fig. 141, I.) on the three radii of circle 1 the three sepals, on the three inter-radii of circle 2 the three petals,

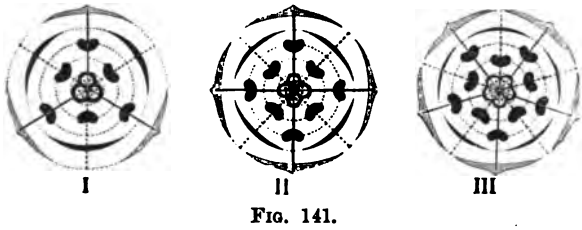


FIG. 141.

Trimerous, tetramerous, and pentamerous floral diagrams.

on the radii of circle 3 and inter-radii of circle 4 the six stamens, and, finally, insert the ovary as shown in the figure, and the trimerous floral diagram is complete.

To construct the tetramerous diagram, begin as before by drawing five circles (Fig. 141, II.), and divide the circumference of the outermost into four equal parts. By connecting the points a, b, d, e by straight lines passing through the centre (c) of the circles, we get the four radii $a\ c$, $b\ c$, $d\ c$, and $e\ c$. If we now bisect $\angle\ a\ c\ b$ and $\angle\ b\ c\ d$, and produce the lines $a^1\ c$ and $b^1\ c$ to the points d^1 and e^1, we obtain the inter-radii $a^1\ c$, $b^1\ c$, $d^1\ c$ and $e^1\ c$. The tetramerous diagram has thus *four radii* and *four inter-radii.* The parts of the flower may now be filled in, as shown in the description of the construction of the trimerous diagram.

The *pentamerous diagram* is constructed in a similar manner. The circumference of circle 1 (Fig. 140, III.) is divided into ten equal parts, and we then proceed as in the construction of the trimerous diagram. We thus get the *five radii* $a\,c$, $b\,c$, $d\,c$, $e\,c$, $f\,c$, and the *five inter-radii* a^1c, b^1c, d^1c, e^1c, f^1c. The parts of the flower are drawn in as before.

In the trimerous and pentamerous diagrams every second radius is in the same straight line as every second inter-radius; in the tetramerous diagram every two radii and every two inter-radii are in the same straight line.

The size of the angles is worth noting :—

(*a.*) In the trimerous diagram $\angle a\,c\,a^1 = 60°$, $\angle a\,c\,e = 120°$
(*b.*) In the tetramerous diagram $\angle a\,c\,a^1 = 45°$, $\angle a\,c\,b = 90°$
(*c.*) In the pentamerous diagram $\angle a\,c\,a^1 = 36°$, $\angle a\,c\,b = 72°$

Number and Arrangement of the Parts of the Flower.

From the floral diagram we are able to make out the following points :—

(*a.*) The number of parts in the flower;

(*b.*) The position which they occupy relatively to one another.

It leaves us, however, in ignorance of their form.

(*a.*) *Number of Parts.* — The very expression tri-, tetra-, or pentamerous floral diagram is an index to the normal number of parts to be met with in each whorl of the flower. As a rule all the parts are either in threes or fours or fives; much more rarely we find that one part falls below or rises above the others in the number of its divisions. When this does happen, the irregularity is generally in the ovary, the number of whose parts seems to be most subject to variation. In Fig. 142, for example, we have two diagrams of *Deutzia glabra*, a common greenhouse plant. The calyx, the corolla, and the two whorls of stamens are each pentamerous, but the ovary is trimerous (is three-celled, I.). The same plant may also have a four-celled ovary (II.) In the flower of love-in-a-mist (*Nigella arvensis*) are five sepals, eight petals, 5 × 8 stamens, and five ovaries (fruit a schizocarp, ovaries partly united).

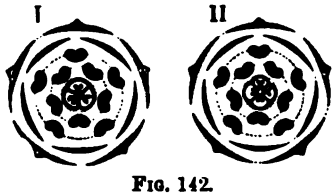


FIG. 142.

Diagrams of *Deutzia glabra*, one with three-celled, the other with four-celled ovary.

(*b.*) *Arrangement of Parts.*—All the parts of the flower are so arranged that either a radius or an inter-radius passes through their centre (they are either on a radius or an inter-radius). If there are, as often happens, two whorls of stamens, the arrangement is usually as follows:—The sepals are on the radii, the petals on the inter-radii, the stamens of the outer whorl on the radii, the stamens of the inner whorl on the inter-radii, the cells of the ovary on the radii. This holds good either of the tri-, tetra-, or pentamerous floral diagram (Fig. 141).

In this case the sepals, outer stamens, and cells of the ovary lie all in one straight line on the radii, the petals and inner stamens in one straight line on the inter-radii.

When one of two parts lies on the radius, the other on the inter-radius, they are said to be *alternate*, because the central axes of the members of the one set occupy the spaces between the members of the other (*e.g.*, sepals and petals in the three diagrams in Fig. 141). The *whole diagram* is said to be alternate when all the parts of the flower are arranged alternately on radii and inter-radii (Fig. 143, I.); such diagrams are very common. There are probably no diagrams in which *all* the members of the different whorls are *opposite* (*i.e.*, situated either on radii or inter-radii, Fig. 143, II.), and which are accordingly called *opposite* floral diagrams. (The diagrams in Fig. 143 have only one whorl of stamens, not two, like those we have hitherto dealt with.)

The Theoretical Diagram.—If we compare the diagrams of a number of *similar plants*, we observe that they are either *perfectly alike*, or at least agree in most points, and present only slight variations. All plants of the lily species, for example, are pretty similar; such are the tulip, the hyacinth, the white lily, the tiger lily, the Turk's-cap lily, the snake's-head, and fritillary, &c. All these have a similar trimerous diagram—three sepals (I., II., III., Fig. 144), which are not green, but coloured like the flower; three petals (1, 2, 3, Fig. 144), 2 × 3 stamens, and a three-celled ovary, each cell containing two seeds,

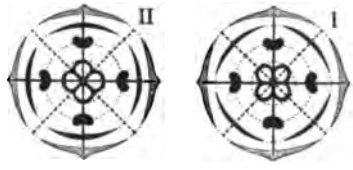


FIG. 143.
Diagrams.—I. Alternate, II. Opposite.

as is seen in transverse section (comp. Fig. 141, I.). The parts are all alternate.

FIG. 144.

Flower of the tulip (*Tulipa Gesneriana*); two-thirds nat. size. I., II., III., Outer perianth (sepals); 1, 2, 3, Inner perianth (petals).

Plants similar in some respects to the lilies are the rushes, the palms, the bamboos, and the grasses. Let us examine the diagram of each of these plants in turn.

The flowers of the *rushes* appear at first sight to be very unlike lilies, but this apparent want of resemblance is due to the fact that the rushes have very small and inconspicuous floral envelopes, while those of the lilies are very large and striking. The number and arrangement of parts is exactly the same in rushes and in lilies, so that, indeed, the floral diagram of the lily (Fig. 141, I.) would stand equally well for that of the rush.

The flowers of the *palms* resemble those of the rushes in this respect, that their flowers are likewise small and inconspicuous. They, too, have three sepals, three petals, 2 × 3 stamens, and a three-celled ovary. But while the cells of the ovaries of the lilies and rushes always contain several seeds, those of the palms contain only one. This peculiarity can easily be expressed diagrammatically, as is shown in the diagram (Fig. 145, I.).

In tropical countries a common plant is the *bamboo*, which, properly speaking, is a sort of grass, although it grows as high as

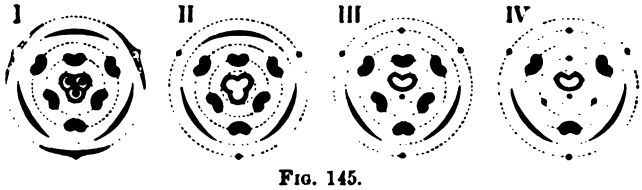


FIG. 145.

Diagrams.—I. Palm; II. Bamboo; III., IV. Grasses.

a tree. Their manner of growth and general appearance is not unlike that of many palms, and the same applies to the structure

of their flowers. These exactly resemble the flowers of the palm in the number and arrangement of their parts, but the calyx is entirely awanting, and the ovary is one-celled and one-seeded. If we construct a diagram of the bamboo, its appearance is something as follows (Fig. 145, II.):—As already said, there is no calyx; the calyx-circle therefore remains blank. If the calyx were present it would have three sepals, to correspond with the prevailing number of the other parts of the flower. In order to indicate that the three sepals are awanting, we mark the place they would have occupied by three dots. The diagram of the bamboo begins in reality on the second circle, where we find the three petals; then follow the third and fourth circles, each with three stamens alternating with one another, and lastly comes the fifth with the one-celled, one-seeded ovary. It follows from the shape of this ovary that it, too, must be trimerous; we can see in the diagram the three carpels of which it is composed.

The floral diagrams of the true grasses are of a yet more simple type. A grass which comes very close to the bamboo in structure is the *rice-plant* (Fig. 145, III.). Its flower is to be distinguished from that of the bamboo by the following peculiarities:—Whereas the bamboo flower has three petals, that of the rice plant has only two; the missing petal should occupy the position indicated in the diagram. Moreover, one carpel of the one-celled ovary is undeveloped, namely, that which lies nearest the two petals. Let these missing members, too, like the missing sepals, be indicated by dots, and we shall get the diagram, Fig. 145, III.

The flowers of our common meadow grasses essentially resemble the one just described, only in their case the three stamens of the fourth circle (the inner whorl) are also awanting; the grass diagram is given in Fig. 145, IV.

A study of Fig. 146 will make this clearer. In I. we have an entire grass spikelet, bearing two flowers enclosed in two scale-like bracts (*glumes*) (*a*, *b*). In II. we have the lower flower more highly magnified. At the termination of the flower-stalk are two "flowering bracts" (the outer and inner *paleæ*) which enclose the true flower. This consists of two small white, often thickish, petals (*i*, *the lodiculæ*), three long stamens (*e e*), and a rounded ovary, with two long feathery stigmas (*f*). From the fact that there are two stigmas we infer that the ovary is composed of two carpels.

We thus see that in the flowers of these plants, the bamboos

as well as the grasses, certain parts are absent which we should expect to find, from our knowledge of the typical structure of

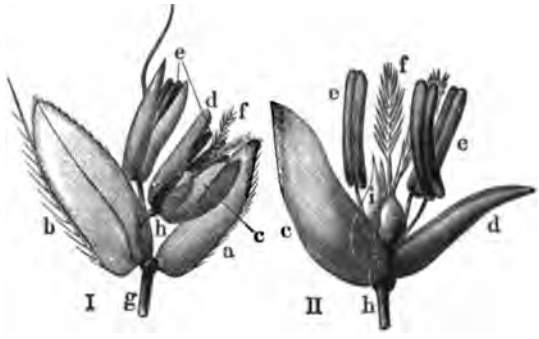


FIG. 146.

A grass (*Holcus lanatus*).—I. Spikelet with two flowers (enlarged); II. The lower flower, more enlarged. *g* Flower-stalk, *a b* Glumes, *c d* Paleæ, *i* Lodiculæ, *e* Stamens, *f* Ovary with stigmas, *h* Stalk of single flower.

flowers closely related to them. From this point of view one might therefore call such flowers irregular or undeveloped. By *comparison* of these flowers with those of kindred plants, it is possible for us to indicate in their diagrams the exact positions which the missing parts ought to fill. The right hand diagram in Fig. 147 shows the floral diagram of a grass, such as we obtain by *direct* observation; the other shows the diagram of the same plant completed by filling in the missing parts, whose position we know by *comparative* observation.

FIG. 147.
Empirical and theoretical diagram of a grass-flower.

Such diagrams as show only the parts actually found in the bud are called empirical (i.e., *directly observed*) *diagrams. Such diagrams as show not only the parts found in the bud, but also indicate all others which are known to be wanting from general comparative observation, are called* theoretical *diagrams.*

When the flower is yet in the early stages of development (*i.e.*, is a very small bud), we often find rudiments of those parts which are awanting in the full-blown flower, and which are indicated in the theoretical diagram by dots. For example, in flowers

where the second whorl of stamens is absent in maturity, it may be found in embryo in the bud. Its presence is indicated, like that of the other whorl, by a series of small prominences. Its development is arrested, however; the stamens cease to grow, and by and by all trace of them disappears. In other cases, again, no trace of missing organs is found, even in the bud, *e.g.*, the inner whorl of stamens in the grass-flower.

Male and Female Flowers.—Curious examples of arrested development of parts occur among those flowers which we before spoke of as male (♂) and female (♀). These, too, can easily be represented diagrammatically. In male flowers the ovary circle is absent; their diagram therefore assumes the form shown in Fig. 148, I.; in female flowers all the stamens are absent, see Fig. 148, II.; the diagram of a neuter flower is shown in Fig. 148, III.; the diagram explains itself. Plants bearing flowers, some of which are male, others female, require a diagram for the representation of each sex.

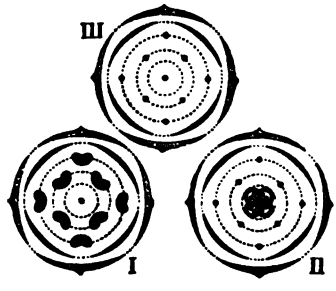


FIG. 148.

Floral Diagrams. — I. Male; II. Female; III. Neuter flowers.

In male flowers the ovaries, in female flowers the stamens, are usually entirely suppressed; but in many plants, some of whose flowers are male, others female, we find in the male flowers rudimentary ovaries, in the female rudimentary stamens. These appear as little knobs, projections, or hair-like bodies, and show plainly that the peculiar form of the fully developed flower is the result of suppression. These traces or rudiments teach us that the unisexual flower is developed from the ordinary hermaphrodite form.

Regular, Symmetrical, and Irregular Flowers.—If in any of the typical floral diagrams (Fig. 141) we prolong one of the radii or inter-radii to the circumference of the circle, we find that it divides the diagram into two halves, a right and a left. The halves are symmetrical—that is to say, the one is of exactly the same shape and size as the other. If we draw one of the diagrams on paper, and cut it into halves with a pair of scissors, and afterwards apply the cut edge to the surface of a mirror, we see as it were a complete diagram, the one-half formed by the paper, the other by its reflection. Everything which in the one

lies, say, to the right, occupies in the reflection a corresponding position to the left, and *vice versa*.

These remarks do not apply to one particular radius or interradius, but to all alike, so that we can divide the trimerous diagram in three, the tetramerous diagram in four, the pentamerous diagram in five different ways, into symmetrical halves.

All diagrams (and their corresponding flowers) which can be divided into two exactly similar halves, in a variety of ways, are regular.

There are other diagrams, however, which can be divided into similar halves only in one direction, *e.g.*, bird-vetch (*Vicia cracca*), Fig. 149, I. This can only be divided symmetrically in the direction indicated by the arrow; a section made so as to cross the arrow at any point cuts the flower into two parts, one of which would contain a greater number of the organs of the flower than the other.

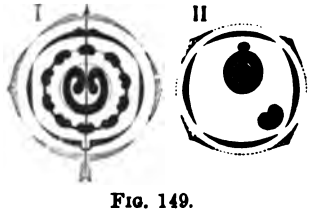


FIG. 149.

I. Symmetrical diagram of bird-vetch (*Vicia cracca*); II. Unsymmetrical diagram of ladies' mantle (*Alchemilla arvensis*).

All diagrams (and their corresponding flowers) which can only be divided into two exactly similar halves in one direction are symmetrical.

Symmetrical diagrams often develop from regular forms by suppression of parts in the latter. One example of this we have already had when considering the theoretical diagram (Fig. 145). The diagrams of the palm and bamboo are *regular*; they can be cut into symmetrical halves in three different directions. The diagrams of rice and other grasses, again, are *symmetrical*, because they can only be cut into symmetrical halves by a line running in a vertical direction through their centre.

Symmetrical diagrams may arise in many different ways from the primary types, by extinction of certain parts. Nature, too, we find, forms the most varied symmetrical flowers, which may all be traced back to the regular three, four, or five parted original.

Finally, there are certain diagrams (and corresponding flowers) which cannot in any way be cut into two symmetrical halves. An example of such a diagram is that of ladies' mantle (*Alchemilla arvensis*), Fig. 149, II. The flower belongs to the tetramerous type; it has, however, only one stamen, which lies

to the right, and one ovary, which does not lie in the centre of the flower, but is pushed upwards a little (is eccentric).

All diagrams (*and their corresponding flowers*), *which cannot be divided into similar halves are* irregular.

ÆSTIVATION, OR ARRANGEMENT OF THE FLORAL ENVELOPES.

When considering the flower of mock orange blossom (Fig. 139), we saw that in the bud the floral envelopes all overlap each other in a certain manner. Even in a fully opened flower we can easily see that the right margin of one petal extends for some way over the left margin of the next. This is termed *overlapping*, because one part of one leaf partially overlaps a part of the next.

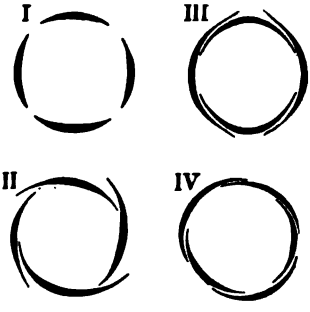


FIG. 150.

Æstivation.—I. Valvate; II. Twisted; III. Decussate; IV. Quincuncial.

Floral leaves may be arranged in the bud in various ways; the most important are as follows:—

(1.) When there are four petals or sepals arranged in opposite pairs, so that both margins of the two outer overlap both margins of the two inner, the arrangement is said to be *decussate* or *alternate* (Fig. 150, III.).

(2.) When the leaves are so arranged that one margin of one leaf overlaps the margin of the one following it, and has its other edge overlapped by the one preceding it, the æstivation is said to be twisted (Fig. 150, II.).

(3.) When in a pentamerous flower two leaves have both their margins overlapped, two others have both their margins overlapping, and a fifth has one margin overlapped, the other overlapping, the arrangement is said to be *quincuncial* (Fig. 150, IV.).

(4.) When the margins of the leaves meet each other but do not overlap, the arrangement is said to be *valvate* (Fig. 150, I.).

We need scarcely say that it is very easy to show in the floral diagram the manner in which the leaves overlap. In most of the foregoing diagrams, however (with the exception of Figs. 138 and 139) no attention has been paid to this, and in future it will only be indicated where it is of special importance.

When a flower is fully expanded it is frequently extremely difficult, nay, impossible, to tell in what manner the parts of its floral envelopes are arranged. The bud, therefore, is usually chosen when the mode of arrangement is to be examined. All that need then be done is to make a transverse section in the manner shown with the bud of *Philadelphus* (Fig. 138), when the mode of arrangement at once becomes evident.

Coalescence or Cohesion of Parts.—We have already seen in Part I. that it is very common for one part of a flower to unite with another. For example, *similar* parts may unite, *e.g.*, the sepals of the calyx, the petals of the corolla, or adjacent stamens; while almost without exception the carpels of the ovary have completely coalesced. In addition to this, however, we may have *adnation* or union of *dissimilar* parts, *e.g.*, the stamens with the petals, or with some part of the ovary, &c. These peculiarities may also be perfectly well indicated in the diagram. If the petals have coalesced among themselves, as in the case of the dead-nettle (*Lamium album*, see Fig. 151, also Fig. 102), this may be shown in the diagram by short curved lines drawn between them (see Fig. 151). If, as very often happens, we have besides a union of the stamens with the petals as in *Symphytum officinale* (see also corolliflorals in general), the coherence of the petals is denoted by the curved lines, the adnation of the stamens by short strokes uniting them with the petals (Fig. 152, I. II.).

Fig. 151.

Diagram of dead-nettle (*Lamium album*) with united petals.

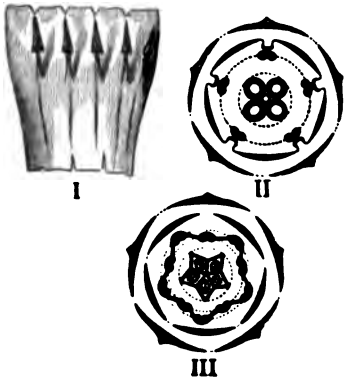


Fig. 152.

Coalescence of Parts.—I. Corolla of *Symphytum officinale*, with adnate stamens; nat. size. II. Diagram of the same flower; III. Diagram of meadow crane's-bill (*Geranium pratense*), with stamens united.

In Fig. 152 we have also the diagram of a flower whose *stamens* have cohered (*Geranium pratense*); it needs no further explanation.

Reduplication of Parts.—Whereas in many flowers we find certain parts awanting or suppressed, in others we find that they

exceed in number those of the fundamental type. This augmentation of number is termed *reduplication*, by which term is expressed the fact that the augmentation has not taken place at haphazard, but in accordance with the general type upon which the flower is formed. Reduplication, or regular multiplication, may be either *tangential* or *radial*.

By the term *radial* is meant the direction corresponding to a radius or inter-radius, by *tangential* the direction at right angles to the former. The tangent may be expressed by a line drawn at right angles to the extremity of a single radius.

(1.) As the result of tangential reduplication, we find the doubled, tripled, or quadrupled floral members on circles exactly corresponding to those of the floral diagram of the fundamental type. In Fig. 153, I. we have the diagram of *Alisma Plantago;* it is formed on the trimerous type. Sepals and petals are normal, but the inner whorl of stamens is absent, the outer reduplicated, so that instead of one stamen at each of the proper points in this stamen-circle, we find two. The ovary circle is at the same time quadrupled, so that instead of the normal three cells we have twelve.

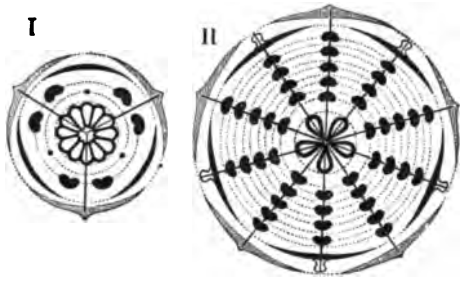


FIG. 153.

Reduplication of Parts.—I. Diagram of *Alisma Plantago;* stamens and ovary tangentially reduplicated. II. Diagram of *Aquilegia vulgaris;* stamens radially reduplicated.

This diagram, therefore, does not differ from the type in the *number* of its stamens, but in their *position* (comp. Fig. 141, I.). We thus see how important, for the drawing of a correct diagram, is an exact knowledge of the position of the parts.

(2.) As the result of *radial reduplication* we find that between the normal number of circles in the type (usually four or five) it is necessary to insert, at one point or another, other circles, on which in the diagram the parts may be laid down, say, from 6 to 14. An example will serve to make this clearer. In Fig. 153, II. we have the diagram of *Aquilegia vulgaris.* The flower is pentamerous, but in place of the normal two stamen-

circles, we have here nine, with five stamens each. The first five are situated on the radii, the second on the inter-radii, the third again on the radii, and so on. The normal number of the stamens which we should have expected is here increased to forty-five.

The consequence of both forms of reduplication is the same, namely, to increase the number of organs. There is this difference, however: in tangential reduplication the normal number of the circles is not altered, and the reduplicated parts all lie at equal distances from the centre; whereas, in radial reduplication, the normal number of circles is increased, and the distances of the reduplicated parts from the centre are either increased or diminished. Both forms of reduplication may occur in the sepals, the petals, the stamens, and the ovary. When both forms occur in one flower, the result is such as we see in the stamens of the mock orange, for example, whose arrangement we are now for the first time in a position thoroughly to understand (comp. Fig. 138 and Fig. 139).

Peculiar Variations and Irregularities in the Diagram.—Hitherto we have only spoken of tri-, tetra-, and pentamerous diagrams, but it must be remembered that besides these we have also forms with two and six floral members on a circle, *i.e.*, di- and hexamerous diagrams. These, however, are so rare that in a text-book of such limited scope as this they may fittingly be omitted.

Further, we sometimes meet with diagrams in which the number of parts in the individual circles differ. This is to be regarded simply as a variation of one or other of the original types dependent upon peculiar circumstances in the development of each circle, and not as a separate form. This subject has been already referred to; for an example see Fig. 142.

Finally, we must note that sometimes we find a certain floral member not lying on any of the ordinary radii or inter-radii of the type, but on a special radius of its own. Such cases are rare, however, and will be treated of further on.

Principles of Classification.

Most of the different plants and animals in the world have been submitted by botanists to a searching scrutiny, with the result that although certain classes may be different, there are yet certain points of *similarity* characterising whole species, certain points of *dissimilarity* distinguishing them from others. Every one will admit, for example, that the sweet violet and the pansy are more alike than the pansy and the dead-nettle

(*Galeopsis*), or that the dead-nettle and the hemp-nettle (see Fig. 86, also Figs. 189 and 192), are more alike than the hemp-nettle and the pansy.

In this way plants and animals have been *classified* according to their greater or less resemblance to each other. This classification has been so arranged that in the vegetable kingdom, with which we have here to do, those plants which agree in the greatest number of points have been placed *nearest* each other, those which agree in the fewest, farthest away from each other.

The classification of all plants according to their points of similarity is called Systematic Botany.

Before entering on the study of the principles of classification in either botany or zoology, we must first get a distinct idea of what is meant by a *species* (of plants or of animals).

To define *species* is no easy task: we shall best be able to understand its meaning if we take a few examples.

As every one knows, the young organisms produced by a particular animal or plant all possess many points of similarity, although they are never *exactly* alike. For example, we should never mistake the young of the cat for the young of any other animal, because all possess in common certain distinctive peculiarities which we always associate with the animal indicated by the term "cat." At the same time we are always able, by differences in colour, marking, and so on, to distinguish the individual members of such a group of similar animals one from another—that is to say, we discover among them many points of dissimilarity. If, however, we compare the points of similarity with the points of dissimilarity, we shall find that the former *far exceed* the latter, and that the disagreement only occurs in certain *minor* particulars. The excess of points of similarity over points of dissimilarity is so apparent, that we should never hesitate in classing these young animals as cats, even if we did not know that they were the offspring of the same animal. The same applies to the horse, differences of colour, size, and strength in the individual never being capable of misleading us as to the species of animal he belongs to.

Nor is it otherwise when we come to plants. The different sorts of pansies in our gardens would never be mistaken by any one for any other flower, although they present the utmost variety of colour and size. (These varieties are the result of long years of cultivation of the common wild heart's-ease).

We may, therefore, define species as follows:—*By "species" we understand the total number of individuals, whether animals or plants, which do not differ from each other any further than do the offspring of a single individual, animal or vegetable.*

A greater or less number of species having certain distinguishing features in common is called a *genus.* This, too, can best be shown by an example:—The horse, the ass, and the zebra are animals which may be distinguished from each other at a glance. If now we leave the points of difference out of account, and concentrate on the points of agreement, we shall find that these three animals resemble each other in a number of ways. All have almost the same formation of skull, twelve front teeth, four side teeth, and twenty-four back teeth, while in each only one toe (the hoof) is fully developed, &c. &c. These points of agreement are such evident proofs of relationship that they justify us in classing these animals together in one genus (horse). In like manner the cat, the lion, the tiger, the leopard, the lynx, &c., form one genus (cat), and the dog, wolf, fox, and jackal, another (dog).

In plants, *e.g.*, the pansy, the sweet violet, and the dog violet belong to one genus (violet), for although these three species seem to be distinct from one another in size and colour, and in the shape of the leaves, yet the form of the flower, the arrangement of the petals, the formation of the capsule, the placentation of the seed, and so on, are so much alike that we must regard the flowers as belonging to one genus (violet).

From what has been already said, it follows that the meaning attached to the word genus is somewhat arbitrary, and depends on the degree of importance which one attaches to the various points of agreement between different species. As, however, the genus is a necessary item in the classification of natural objects, its limits have for long been prescribed, at least in the case of the better known animals and plants.

On the classification of animals and plants into genera and species, the prevailing zoological and botanical nomenclature depends. It was first introduced by Linnæus about the year 1735. All the scientific names used in botany and zoology are derived from Greek or Latin. Greek words, when used for this purpose, are Latinised.[1] The

[1] *Examples.*—The full botanical name of the anemone is *Anemone nemorosa.* The plant had already been called *Anemone leimonia* (growing in the meadows) by Theophrastus, and Pliny introduced the term into Latin (Hist. Nat. XXI., 11). *Alyssum,* in another case, was the Latin form of the Greek *Alysson, Origanum* of *Origanon,* &c.

reason of this is that we may suppose students of botany and zoology to have some acquaintance with Latin; and that, therefore, whatever may be their native tongue, Latin names will be understood by all. It would be utterly impossible for any scientist to be familiar with all the common names of the various plants and animals in all the living languages, yet this would be necessary (were there no general medium of expression) for the study of zoological or botanical works in the various languages. Latin affords this general medium, and the Latin names of animals and plants are therefore those used in the scientific world, no matter what may be those used popularly in England, Germany, France, or Italy.

Linnæus named genera as well as species in this manner; we have therefore *generic* and *specific* names for all plants and animals. In order to give a scientific name to any organism, we place the name of the genus before that of the species, so that animals and plants may be said to have, like man, a Christian name and a surname. The *genus* horse is in Latin *Equus*, the *species* horse *caballus;* in zoology, therefore, the horse is known as *Equus caballus.*

The Linnæan method of naming animals and plants is termed the *double* or *binomial* system of nomenclature. Here are some examples:—

ANIMALS.	PLANTS.
GENUS—Horse, *Equus.*	GENUS—Violet, *Viola.*
1. Species—Horse = *Equus caballus.*	1. Species—Pansy = *Viola tricolor.*
2. ,, Ass = *Equus asinus.*	2. ,, Sweet violet = *Viola odorata.*
3. ,, Zebra = *Equus zebra.*	3. ,, Dog violet = *Viola canina.*
GENUS—Dog, *Canis.*	GENUS—Poplar, *Populus.*
1. Species—Dog = *Canis familiaris.*	1. Species—White poplar = *Populus alba.*
2. ,, Wolf = *Canis lupus.*	2. ,, Aspen = *Populus tremula.*
3. ,, Jackal = *Canis aureus.*	3. ,, Black poplar = *Populus nigra.*
4. ,, Fox = *Canis vulpes.*	4. ,, Pyramidal poplar = *Populus pyramidalis.*
GENUS—Cat, *Felis.*	GENUS—Plum, *Prunus.*
1. Species—Cat = *Felis catus.*	1. Species—Sloe = *Prunus spinosa.*
2. ,, Lion = *Felis leo.*	2. ,, Cherry = *Prunus cerasus.*
3. ,, Tiger = *Felis tigris.*	3. ,, Bird Cherry = *Prunus avium.*
4. ,, Leopard = *Felis pardus.*	4. ,, Damson = *Prunus domestica.*
5. ,, Lynx = *Felis lynx.*	5. ,, Apricot = *Prunus armeniaca.*

In like manner several Genera are united to form a *Family,* several Families to form an *Order,* several Orders to form a *Class,* several Classes to form a *Type,* and all Types to form a *Kingdom* (animal or vegetable).

In the following table the greater the division the nearer it

stands to the left side of the page, and the larger the type in which it is printed:—

KINGDOM.

TYPE.

CLASS.

ORDER.

FAMILY.

GENUS.

SPECIES.

Examples.—The Lion (*Felis Leo*).

Kingdom—Animal Kingdom (*Animalia*).
Type—Animals with backbone (*Vertebrata*).
Class—Animals which suckle their young (*Mammalia*).
Order—Beasts of prey (*Carnivora*).
Family—Cat-like beasts of prey (*Felidæ*).
Genus—Cat (*Felis*).
Species—Lion (*Felis Leo*).

SYSTEMATIC ARRANGEMENT OF THE HIGHER PLANTS.

In the following remarks we shall confine ourselves solely to the consideration of the higher plants, namely, those which have flowers consisting of floral envelopes, stamens, and ovary. These are termed *Phanerogams* or *Flowering Plants*. Of the lower plants, *i.e.*, the fungi, algæ, mosses, ferns, horse-tails, and even conifers, we shall at present say nothing. Their structure is much more difficult to understand, and may therefore be more appropriately examined when our knowledge is somewhat more extensive.—(See Part V.)

No phanerogams are altogether without flowers, but in many they are so small that they can only be seen by the aid of a lens.

It was formerly supposed that some plants had no reproductive organs, but research has proved this to be incorrect. Linnæus even went the length of saying that all plants whatsoever must have flowers and fruit, even those in which the most improved optical appliances have as yet been unable to discover any.[1]

[1] Linnæus says—"Omnis species vegetabilium flore et fructu instruitur, etiam ubi visus eos non detexit."

Monocotyledons and *Dicotyledons*.—In the seed of every phanerogam there is, as has been already said, the germ of a new plant, which has either *one* or *two* seed-leaves (*cotyledons*).

All plants having only one seed-leaf are termed Monocotyledons; all plants having two seed-leaves are termed Dicotyledons.

As *all* phanerogams have either one or two seed-leaves, it follows that the division of plants into monocotyledons and dicotyledons is of the greatest importance. Of course, the best way to find out whether a plant is a monocotyledon or a dicotyledon would be to plant one of its seeds, and see whether one or two leaves appeared when it began to grow. Owing to the circumstances of the case, however, this is very seldom possible, so we have to resort to other means in order to obtain the necessary information. An experienced botanist may examine the embryo with a lens, and thus be able to discover the number of cotyledons it contains, but in very small seeds such examination is accompanied by extreme difficulty.

Without going to the seed, however, there are certain characteristics distinguishing monocotyledons from dicotyledons which are easily recognisable. These are as follows:—

(1.) The flowers of monocotyledons are nearly all arranged in whorls of three, the dicotyledons in whorls of five or four.

All our indigenous monocotyledons have trimerous flowers with the exception of *Smilacina bifolia*, *Paris quadrifolia*, and a few others, whose flowers are tetramerous. The greater proportion of dicotyledons have pentamerous flowers, but tetramerous flowers are not unusual. Trimerous dicotyledons are almost unknown in this country.

(2.) The leaves of monocotyledons have parallel venation, those of dicotyledons are reticulated.

The leaves of our indigenous monocotyledons are always simple. The veins usually spring from one point at the base (Fig. 50), and run parallel to each other through the length of the leaf, or they have a strong midrib (Fig. 33, *a*) from which secondary veins arise. In the latter case the veins of the third order run parallel to one another, and do not form an irregular network.

The leaves of dicotyledons may be either simple or compound. Branches are always given off from the midrib, and the small veins form an irregular meshwork (Fig. 23, *a*.) By this latter feature we are able to distinguish the leaves of such a plant as *Plantago major*, where the principal veins all arise near the base, as those of a dicotyledon.

TYPE I.

MONOCOTYLEDONS.

Monocotyledons are plants which have only one seed-leaf. Their flowers are arranged in whorls of three (occasionally four), their leaves are mostly simple, their venation parallel.

The most common form of flower is the regular trimerous one, which is thus the fundamental type on which all monocotyledonous flowers are constructed (Fig. 154). It has two floral envelopes, whose parts are arranged alternately, and are sometimes wholly or in part united, in which case the flower has a six-toothed rim (Fig. 155). It has six stamens arranged in two whorls alternating with each other, and with the parts of the floral envelopes; the ovary is three-celled, the cells opposite the sepals and many-seeded, the seeds arranged in two rows (Fig. 156).

FIG. 154.

Floral diagram of trimerous flower of monocotyledon, with two whorls of stamens.

FIG. 155.

Flower of monocotyledon (bell hyacinth, *Muscari racemosum*); parts of floral envelopes coalesced.

FIG. 156.

Ovary of tulip (*Tulipa Gesneriana*); section about six times enlarged.

Variations from the fundamental monocotyledonous type may occur in the following ways:—

1. By suppression of one or both floral envelopes;
2. By suppression of one staminal whorl, or of both, with the exception of one or two members;
3. By reduplication of stamens;
4. By development of single-seeded cells in ovary;
5. By development of single-seeded ovary;
6. By reduplication of cells of ovary or of one-seeded ovary.

Variations which may come under 1, 2, and 5 have usually the result of producing a *symmetrical* flower.

The flowers stand singly on the stem, or form a spike, a panicle, a spadix, a raceme, or a loose corymb.

The *fruit* is a capsule, berry, nut, caryopsis, or achene; and may be six, four, three, two, or one celled.

The *stem* of all our indigenous monocotyledons is *herbaceous*, sometimes jointed. Monocotyledonous *trees* (palms, dracænas) are only found in the tropics.

The *leaves* of indigenous monocotyledons are parallel veined, simple, narrow, linear, or sword-shaped, lanceolate, ovate, never compound. (The palms form the only exception to this last statement.)

The root is formed only of secondary rootlets. The growth of the primary root is arrested soon after the seed has sprouted.

Monocotyledons are to be found in all parts of the world. There are about 19,000 species known.

KEY TO ORDERS OF MONOCOTYLEDONS.[1]

I. Floral envelopes large, usually forming a perianth. Fruit usually a capsule.

A. Flowers regular or symmetrical, with three or more stamens.

a. Ovaries many, or one and six celled; flowers mostly unisexual, — 1. HELOBIÆ or MARSH LILIES.

b. Ovary single, with not more than four cells, flowers hermaphrodite.

1. Ovary inferior, ... — 2. ENSATÆ or SWORD LILIES.

2. Ovary superior, ... — 3. CORONARIÆ or LILIES.

B. Flowers symmetrical, stamens one or two, . . — 4. GYNANDRÆ or ORCHIDS.

II. Floral envelopes small and scale-like, or absent; fruit never a capsule.

A. Inflorescence, a spadix, surrounded by a spathe, . — 5. SPADICIFLORÆ or SPADIX-FLOWERS.

B. Inflorescence, a spike, panicle, or loose corymb, without a spathe. — 6. GLUMACEÆ or GLUME FLOWERS.

[1] Compare table at the end of the book.

I.

HELOBIÆ OR MARSH LILIES.

The marsh lilies (*Helobiæ*[1]) are monocotyledons, with large regular flowers. The calyx is composed of three greenish or brownish sepals, the corolla of three white petals (in *Butomus umbellatus* both sepals and petals are bright pink). Stamens six or many; ovary either simple, six-celled and many-seeded, or ovaries many, one-celled, one-seeded; fruit, a dry capsule or achene; flowers seldom ☿, usually monœcious or diœcious; inflorescence, a loose panicle, or flowers standing singly, with two scale-like bracts at the base of the stem (Fig. 157); leaves simple, sword-shaped, elongated, lanceolate, sagittate, or reniform; the base of the leaf-stalk embraces the stem like a sheath; stem angular, often spongy internally, sometimes very short.

FIG. 157.

♂ flower of water soldier (*Stratiotes aloides*); nat. size.

The marsh lilies abound all over the world; they are found in marshy spots; many are water plants with submerged or floating leaves. They are divided into three orders:—

(1.) *Alismaceæ*.—Calyx green; petals white; stamens six or many; ovaries numerous, superior; flowers hermaphrodite or monœcious (Figs. 158, 159); fruits numerous, crowded together, forming a rounded aggregate fruit, each part a one-seeded achene of triangular shape (Figs. 160, 161).—[50.][2]

The Alismaceæ are small, annual herbs, which grow in shallow water, with leaves and flowers above the surface. They are found in the Northern Hemisphere, in Central and South America, North Africa, and New Holland. Indigenous to this country, *Alisma* (hermaphrodite flowers with six stamens) and *Sagittaria* (monœcious flowers with numerous stamens).

(2.) *Butomeæ*.—Floral envelopes similar, rose pink; stamens

[1] Plants which grow in marshy spots (Gr. *helos*, a bog; *bios*, life).

[2] Numbers standing thus [ ] at the end of the description of an order are intended to indicate approximately the number of known species.

nine in two whorls (6 + 3); ovaries six, each many-seeded (Fig. 162), superior; fruit capsular; flowers in umbels, ☿.—[13.]

Perennial marsh plants, with short stems and long, sword-shaped, stiff root-leaves. Inflorescence borne at end of a long leafless stalk (*scape*). Found in Tropical and Central America, where we have several genera with green sepals. Our indigenous genera of *Butomeæ* are found throughout the temperate regions of both hemispheres.

FIG. 158.
Alisma Plantago.

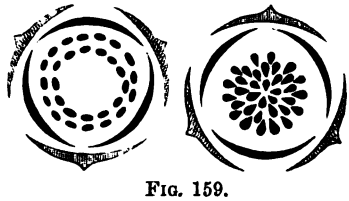


FIG. 159.
Sagittaria sagittæfolia, ♂ and ♀.

(3.) *Hydrocharideæ.*—Calyx green, herbaceous; petals white (Fig. 157); stamens twelve or numerous, united or free; nine to fifteen barren, *i.e.*, without anthers. Ovary inferior; incompletely six-celled and many-seeded, with six divided stigmas (Fig. 163). Flowers monœcious, the ♀ with six or more barren stamens. Fruit in the form of a berry. One or several flowers are enclosed in two membranous or leaf-like bracts, growing at the base of the flower-stalk.—[30.]

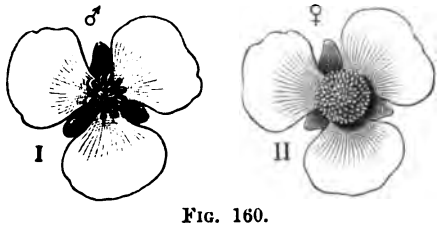


FIG. 160.

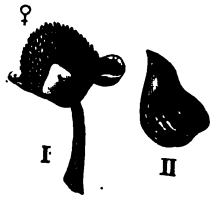


FIG. 161.

Fig. 160.—Arrowhead (*Sagittaria sagittæfolia*); male and female flowers; nat. size. Fig. 161.—Arrowhead (*Sagittaria sagittæfolia*); ovaries (I.) and single fruit (II.), the second enlarged.

FIG. 162.
Butomus umbellatus.

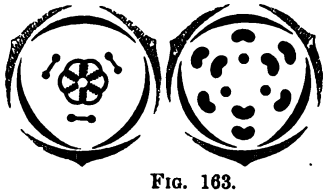


FIG. 163.
Hydrocharis Morsus ranæ.

Perennial water-plants with shortened stems and submerged or

floating leaves. *Hydrocharis Morsus ranæ* is confined to Europe (leaves floating, reniform); so also is the water soldier (*Stratiotes aloïdes*) leaves submerged, linear, spinous-dentate. Other genera occur in North America, Africa, Australia, and Southern Asia. Of late years an American species, *Anacharis canadensis*, a small plant with inconspicuous flowers, has made its way into many European lakes and canals, where it threatens to interfere with the navigation.

II.

ENSATÆ [1] (SWORD LILIES).

The *Ensatæ* or Sword Lilies are monocotyledons with large regular (occasionally slightly symmetrical) flowers. Floral envelopes of six parts, all brightly coloured, either separate or partly united. Stamens three or six. Ovary inferior, three-celled, one or many seeded. Fruit, a capsule.

Land or marsh plants with tubers or bulbs; stem frequently only leafy below; leaves mostly stiff, simple, and sword-shaped, partially embracing the stem. Two orders.

(4.) *Iridaceæ*.—Floral envelopes forming a perianth, of six parts (the outer envelope often very unlike the inner), regular, occasionally slightly symmetrical. Stamens three, placed opposite sepals (inner whorl undeveloped, Fig. 164). Ovary three-celled and many-seeded, with three more or less united styles; the three stigmas often petaloid. —[600.]

FIG. 164. Yellow iris (*Iris pseud-acorus*).

Indigenous to the warmer parts of the Temperate Zones of both hemispheres; especially abundant at the Cape. In this country many species are cultivated, and the yellow iris (*Iris pseud-acorus*) grows wild in marshy spots. The crocus and gladiolus also belong to this order.

(5.) *Amaryllidaceæ*.—Floral envelopes forming a perianth of six parts (occasionally united, and sometimes with outer unlike inner), always regular, sometimes with a corona. Stamens six, in two whorls of three each (Fig. 165). Ovary three-celled, and one or more frequently many seeded, with united style and stigma.—[400.]

FIG. 165. Snowdrop (*Galanthus nivalis*).

Warm, temperate, and tropical regions; the snowdrop (*Galanthus nivalis*), the snowflake (*Leucojum*

[1] Leaves sword-like (Latin, *ensis*, a sword).

vernum), and the narcissus (*Narcissus pseudo-narcissus*) are familiar flowers of this order. Amaryllis and American aloe (*Agave Americana*) are favourite greenhouse plants of this order. The *Bromeliaceæ* (pine-apple family) are related, but we have no representatives in our flora.

III.

CORONARIÆ (*Lilies*).

The *Coronariæ*[1] are monocotyledons with large and conspicuous perianths, or small dry membranous floral envelopes, arranged in one whorl of four, or more usually in two whorls of three or four parts. The flowers are regular; parts of the perianth separate or united (Fig. 66, Fig. 67 *a*). Stamens four, six, or eight. Ovary superior, one, two, or three celled, three or many seeded. Fruit, a capsule or berry.

Mostly perennials with bulbs (Fig. 3 *a*, Fig. 14 *a*), rhizomes, or tubers; stem frequently leafless, except at lower part (scape). Leaves simple, mostly narrow, sometimes grass-like. Two orders.

(6.) *Liliaceæ.*—Perianth large, petaloid, with six, or, rarely, with four or eight parts; ovaries two, three, or four celled, few or many seeded (Figs. 166-168); fruit, a capsule or berry. Leaves usually grass-like.—[1600.]

FIG. 166. Tulip (*Tulipa Gesneriana*).

FIG. 167. *Paris quadrifolia.*

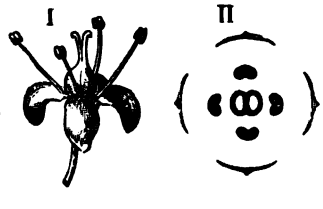


FIG. 168. *Smilacina bifolia.*

The lily order, which comprises a large number of genera, is scattered over the surface of the globe; it is abundant in the warm temperate regions of both hemispheres. Its members are mostly herbaceous (*e.g.*, all our indigenous species), seldom tree-like, its most tree-like representatives being the dracænas of the East Indies and the Canaries.

[1] From *corona*, a crown.

Families of Liliaceæ.

I. Fruit a *capsule*, flower with parts in threes.
  A. Floral envelopes united, with six-toothed rim.
    a. With tuberous or fibrous roots; fruit mostly many-seeded, ... 1. Day Lilies.
    b. With bulbous roots; fruit few-seeded, . 2. Hyacinths.
  B. Floral envelopes free, or very slightly united.
    a. Fruit a capsule; cells few-seeded, . 3. Leeks, &c.
    b. Fruit a capsule; cells many-seeded, . 4. Tulips.
II. Fruit a berry; flowers with parts in threes or fours; parts of the perianth free or united, . . 5. Asparagus, &c.

(1.) *Day Lilies* (*Hemerocallidæ*).—We have no species of this family indigenous. Many species have, however, been introduced as greenhouse or garden plants, *e.g.*, *Hemerocallis*, with yellow or orange-coloured flowers, *Agapanthus*, with blue flowers growing in simple umbels on a long stalk, and *Funkia*, with broad leaves and bright lilac flowers. (2.) *Hyacinths* (*Hyacintheæ*).—Examples of this are the well-known common hyacinth (*Hyacinthus orientalis*), and the bell hyacinth (*Muscari racemosum*, Fig. 109 *a*, and Fig. 155 *a*). (3.) *The Leek family* (*Scilleæ*).—The *leek* and *onion* genus (*Allium*) is especially important as articles of food. Besides, we may note the beautiful blue flowered *Scilla*, a favourite garden spring flower, *Gagea*, and *Ornithogalum* (star of Bethlehem). (4.) *Tulips* (*Tulipæ*).—Examples, tulips, lilies, and fritillary (*Fritillaria imperialis*). (5.) *The Asparagus family* (*Smilaceæ*).—These are plants with parts in threes or four; in threes—asparagus (*Asparagus officinalis*); in fours—*Smilacina bifolia* and *Paris quadrifolia*.

(7.) *Rushes* (*Juncaceæ*).—Perianth small, parts dry, membranous, brownish, not brightly coloured, in threes. Ovary three or one celled, many-seeded or three-seeded. Fruit a three-valved capsule. Leaves grass-like.—[250.]

Small grass-like herbs, with jointed, simple, or branching stems, and scaly rhizome. Common throughout the world, especially in the Temperate Zones—rarer in the Tropics; represented even in the Polar regions. *Juncus* and *Luzula* are our commonest genera.

IV.

Orchids (*Gynandræ*).

The *Orchids* (*Gynandræ*) are monocotyledons with conspicuous, beautifully coloured, symmetrical flowers. Floral envelopes

double, trimerous; calyx and two petals form a casque-shaped upper lip (*a, b, c, e, f*, Fig. 169), the third petal (*d*) unites with two stamens (*l l*), forming the large winged *labellum*. Ovary (*g*) inferior, usually elongated and twisted, whereby it happens that the uppermost petal (the labellum) is the lowest part of the flower, the sepal diametrically opposite, the highest. Of the stamens (*s*) usually only one is fully developed (in *Cypripedium* two); filament confluent with the style, anther has two pollen masses. Ovary three-valved, one-celled, and many-seeded, seeds minute, and attached to parietal placentæ. Fruit, a capsule. Leaves simple.

FIG. 169.
Spotted orchis (*Orchis maculata*).

(8.) (*Orchids*) *Orchidaceæ*.—Characters as above. Of this order we have several dozen species. All the native species are herbs growing in woody or marshy places; height 4 to 25 inches. Numerous species occur in the Tropics, where they exceed all other plants in the size, peculiarity, and splendour of their flowers. Many grow on the branches and stems of trees (Fig. 10), others have a climbing stem with aërial roots like the ivy, and grow upon rocks, &c., *e.g.*, the vanilla (*Vanilla planifolia*) of Central America. From the long siliqua-like capsule of the latter the well-known aromatic spice is obtained.

Indigenous genera are *Orchis*, *Ophrys*, *Neottia*, *Cephalanthera*, and *Cypripedium*, or lady's slipper.—[ca. 6000.]

Connected with the orchids are the *Scitamineæ*, of which order the bananas (*Musaceæ*) are members. *Musa sapientum* and *M. paradisiaca* are species to be met with everywhere in the Tropics. Ginger also belongs to the *Scitamineæ*, the ginger in common use being the root of *Zingiber officinale*. From the root of *Curcuma longa*, another of the *Scitamineæ*, we obtain a kind of arrowroot. The last order connected with the orchids which we need mention is the *Marantaceæ*, to which belongs the much cultivated *Canna*.

FIG. 170.
Orchis maculata.

V.

SPADICIFLORÆ.

The *Spadiciflorœ* [1] are monocotyledons with floral envelopes either absent or small; perianth when present with four or six parts; ovary superior; flowers united to form a fleshy spike (*spadix*). In Fig. 171 the flowers are ♂ and ♀; the former are shaded darker, and consist of four large anthers; the latter consist of a four-celled ovary surrounded by a perianth of four thick short parts. In some species all the ♂ flowers are at the summit, all the ♀ at the base of the spadix; in others, again, the flowers are scattered irregularly. The spike is often branched, *e.g.*, in the palms. The whole inflorescence is enveloped in a large bract or *spatha*, green in the palms, but petaloid in other species (*Araceœ*). Fruit, a nut or berry. Chiefly tropical; often large trees with unbranched trunks and beautiful pinnate leaves. Home species mere herbs. Two orders:—

FIG. 171.

Spadix of a species of *Pandanaceæ* (*Carludovica Hookeri*) with ♂ and ♀ flowers; nat. size.

(9.) *Arums* (*Araceœ*).—Flowers hermaphrodite (Fig. 173) or monœcious (Fig. 172); when monœcious ♂ often placed above ♀. Inflorescence, a spadix thick and fleshy, the summit frequently without flowers; surrounded at the base by a simple bract (Fig. 46); bract occasionally united throughout its entire length to spadix (Fig. 172, I.); floral envelopes usually absent, or with four or six parts, scale-like. When perianth is present the number of stamens corresponds to that of the parts of the perianth; where the perianth is absent the stamens are arranged around a disk supported on a column (Fig. 172, II.); ovaries (Fig. 172, III.) free, three or one celled, one or many seeded; fruit dry or a fleshy berry.—[750.]

[1] Latin, *spadix*, and *flos*, *floris*, a flower.

The *Araceæ* are conspicuous, sometimes large herbs, with shiny, broad, often sagittate, more rarely incompletely pinnate or

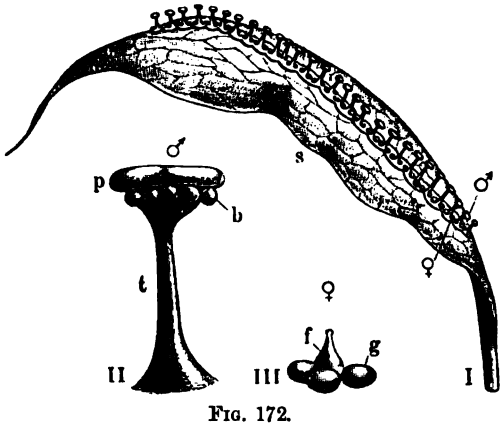


FIG. 172.

Spathicarpa, a South American species of *Araceæ*, showing bract adnate to spadix.—I. Inflorescence, nat. size; II. ♂; III. flower ♀, eight times enlarged; *s* bract, *t* column, *p* disk, *b* anther, *f* ovary, *g* knob-like prominences on ovary.

palmate, leaves (Fig. 33). The bract is usually brilliantly coloured, rarely green (*Spathicarpa*, *Arum*), frequently white (*Richardia africana*), bright red (*Anthurium Scherzerianium*), yellowish (*Monstera*), &c. The Spadicifloræ are mainly natives of the tropics, commonly found growing in marshy spots. Some, like many orchids, grow on trees. Two families:—

FIG. 173.
Acorus Calamus.

(1.) Arums (*Aroideæ*).—Flowers dicœcious. Land plants. *Arum maculatum* (native species).—Lily of the Nile (*Richardia africana*), a common greenhouse plant, *Spathicarpa*, &c.

(2.) *Orontiæ* (sweet-flags).—Flowers ☿: Land and marsh plants. Marsh calla (*Calla palustris*) and *Acorus Calamus* (sweet-flag). The rhizome of the latter is large, greenish, scaly, and strong smelling; it is used in medicine.

The *Lemnaceæ* are sometimes reckoned as a third family. They are small plants, which float on the surface of water, and seldom flower. *Lemna minor*, *gibba*, *polyrhiza*, *trisulca* (home species).

The *Pandanaceæ* and *Cyclanthaceæ* of the tropics are nearly related to the *Araceæ*. These are tree-like plants, with pinnate or sword-shaped leaves, a straight unbranched stem, roots also little branched, and partly above ground. Fig. 171 shows a full-sized spadix of one of the *Pandanaceæ* (*Carludovica Hookeri*).

(10.) *Palms* (*Principes*).—Flowers small, unisexual, with double perianth; both whorls similar, stamens six (rarely

numerous), free or united; ovary superior, having three carpels, each cell one-seeded; frequently, when mature, with only one cell and one seed fully developed. Inflorescence a branched spadix, thickly covered with flowers, and enclosed by several green bracts at the base (*s*, Fig. 174); fruit a nut (Fig. 175) or a berry; one or two seeds (Fig. 176).—[1000.]

The palms are mostly high trees with unbranched, occasionally branched (*Hyphæne thebaïca*) stems, which bear at their summit a

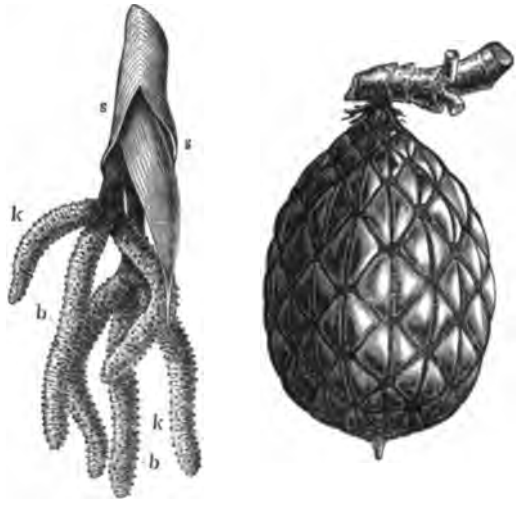


Fig. 174. Fig. 175.

Fig. 174.—Small spadix of a palm (*Borassus flabelliformis*).
Fig. 175.—Nut of sago-palm (*Sagus Rumphii*); three-fourths nat. size.

crown of several or many large leaves (see Fig. 17). The stem is covered through its entire length with the scars of the leaves of former years. The stem is sometimes not cylindrical, but is thicker at the middle than at either end (*Oreodoxa regia*, *Jubæa spectabilis*); it grows straight upwards, or is climbing (*Calamus equestris*, Spanish cane). The leaves are very large, either pinnate or pinnately cleft (cocoa-palm, *Cocos nucifera*; sugar-palm (*Arenga saccharifera*); palmate (*Livistona australis*, *Chamærops humilis*) or simple (*Lodoïcea Seychellarum*). The fruits are nuts (cocoa, Seychelles-palm) or berries (date-palm). The nuts of the sago-palm are covered with hard, regular, woody scales, for which reason this group is termed *Lepidocarpeæ*, or scaly-fruited palms.

Fig. 176. Diagram of palm flower. Hermaphrodite.

The palms are almost exclusively confined to the Tropics, *Chamærops humilis* being the only species found wild in Europe. It extends as far north as Nice, where it forms a thick underwood; it grows plentifully in the more southern part of the course of the Ebro. The uses of the palm are manifold: the fruit, the seeds, the young sprouts of many species are used as food; from others wax is obtained (*e.g.*, the wax-palm, *Ceroxylon andicola*, whose stem is covered with a thick layer of wax, which may be scraped off and prepared for use), or oil (*e.g.*, the oil-palm, *Elaïs guineensis*, from which we get the red palm oil), or again, sago from the pith (sago-palm, *Sagus Rumphii*, a native of the East Indies); from the sap, which flows from the trunk when the latter is tapped, an invigorating drink is made (wine palm, *Oenocarpus distichus*, *Raffia vinifera*). The thin flexible stems of the rattan palms are well known as "Spanish canes," while the hard endosperm of *Phytelephas macrocarpa* of South America is used as a substitute for ivory. From *Calamus Draco*, an East Indian species, a kind of dragon's blood is obtained—a red resinous substance contained in the fruit, and which, when extracted, is dried for use. The large leaves of many species are used by the natives of the tropics to cover their huts, and as a substitute for clothing, and so on.

VI.

GLUMACEÆ.

The *Glumaceæ* are monocotyledons in which the floral envelopes are either absent or very small and husk-like. If the floral envelopes are present, the parts are bristle-like, six bristles or two, small and scale-like. Flowers arranged in spikes, panicles, or loose corymbs (Fig. 114, II.); usually hermaphrodite; sometimes monœcious or diœcious; they do not possess coloured bracts. Ovary superior. The fruit (Fig. 122, *a*) is a simple one-seeded caryopsis or achene.

The *Glumaceæ* are grass-like herbs, with inconspicuous greenish flowers, narrow, linear leaves, which embrace the stem like a sheath, a cylindrical or triangular jointed stem, and a fibrous root. They are found universally from the Equator to the Poles. Two sub-orders:—

(11.) *Grasses* (*Gramineæ*). — Flowers small, outer perianth absent, inner two (*lodiculæ*), thick, whitish, or 0; stamens three (occasionally many, six, two, or one); ovary one-celled, one-seeded, composed of two carpels (Fig. 177) (rarely of only one or of three), bearing two large, white, feathery stigmas. Each flower is protected by two bracts or "flowering glumes," the *paleæ* (*c d*, Fig. 146 *a*), the outer usually awned, the inner two-nerved.

The flowers are arranged in spikelets of two (comp. Fig. 146, I.) or more, which have two bracts or "glumes" (*a b*) at their bases. The spikelets again are arranged so as to form spikes or panicles, so that the panicle of such a grass as rye is said to be *compound*.

Fig. 177. Diagram of grass-flower.

The fruit is a grain, smooth or furrowed longitudinally (the furrow shows the line of coalescence of the two carpels); the seed is inseparable from the pericarp (caryopsis). The large quantity of albumen renders the fruit extremely nutritious; hence the importance of the grasses as articles of food.—[3800.]

The grasses are universally distributed, extending as far north as the utmost limit of vegetation, but chiefly characteristic of the Temperate Zones. With us they are herbs; in the Tropics they not rarely assume the proportions of trees (*e.g.*, bamboo grasses). They are either annuals or perennials. The stem is round, hollow, and prominently jointed; the leaves are narrow and linear, and have each a ligule at their base (Fig. 44, *h*). The uses of the grasses as food for man and beast are well-known. The most important grasses of cultivation are rice (*Oryza sativa*), maize (*Zea Mais*), millet (*Panicum miliaceum*), durra (in Arabia *durra*, in the Soudan *ngáingala*, *Sorghum vulgare*), oats (*Avena sativa*), rye (*Secale cereale*), wheat (*Triticum vulgare*, *Spelta*, *dicoccum*, *turgidum*, and *monococcum*), barley (*Hordeum vulgare*, *Zeocriton*, *distichum*, *hexastichum*). Sugar is obtained from the sugar-cane, a grass reaching a height of about ten feet, originally indigenous to Asia, but now largely cultivated throughout the Tropics. The sugar is contained in the sap of the plant. Just before it flowers the stem is cut and the sap is extracted by pressure. The more familiar wild grasses are rye-grass (*Lolium perenne*), the poisonous darnel (*Lolium temulentum*), *Phleum*, *Alopecurus*, *Dactylis*, *Briza* or quaking grass, *Bromus* (Fig. 144, II.) *Festuca*, &c.

(12.) The *Sedges* (*Cyperaceæ*).—The flowers are hermaphrodite or unisexual, monœcious or diœcious. Floral envelopes usually absent; in their place a cup-shaped sac, surrounding the simple ovary, or a few or many bristles (Fig. 178). Stamens three, inserted below the ovary (hypogynous). Ovary one, one-celled, with one ovule, surmounted by one style, having two or three stigmas. Fruit nut-like; pericarp not adherent to the seed, as in the grasses (achene).—[2000.]

The sedges are annual or perennial herbs, with a branched, sheathed, and scaly rhizome. Their distribution is universal. Stem jointed,

usually triangular, and leafless, except at the lower end. Leaves long, narrow, and linear, flat or roundish. Two families :—

1. *Sedges proper* (*Caricineæ*).—Flowers unisexual, usually monœcious; represented in this country by the genus *Carex* (sedges) containing about sixty British species.

2. *Cyperineæ*.—Flowers hermaphrodite. To this family belongs the famous *papyrus* of the ancients (*Papyrus antiquorum*), now only to be found in the region of the White Nile, and in a particular part of Sicily; other well-known genera are *Scirpus* (bulrush) and *Eriophorum* or cotton grass. *Cyperus esculentus*, a species common in the region of the Mediterranean, bears esculent tubers.

FIG. 178.
Diagram of *Scirpus*.

TYPE II.

DICOTYLEDONS.

The Dicotyledons are plants with two seed-leaves. Their flowers are arranged in whorls of five or four (*Fig.* 179), *their leaves are simple or compound, their venation reticulated.*

The typical form of dicotyledonous flower is regular, pentamerous (or tetramerous), with two floral envelopes, two whorls of stamens, and a whorl of carpels, the arrangement of all the parts being alternate. The members of each floral whorl may be wholly or in part united. The sepals are as frequently united as free, the petals among a large section of dicotyledons are always united, while the coherence of stamens is more rare. Flowers in which the stamens are adnate to the united corolla are more common (Fig. 180). The number of stamens and carpels is very variable.

FIG. 179.

FIG. 179 *a*.
Regular tetramerous and pentamerous diagrams.

The following are some of the more common modes of variation from the fundamental type :—

Variations may arise—

(1.) By suppression of one or both floral envelopes;
(2.) By suppression of either the inner or outer whorl of stamens;

(3.) By abortion of individual members of the staminal whorl;
(4.) By radial or tangential reduplication of the stamens;
(5.) By reduction of the number of seeds (one or more) in the ovary;
(6.) By development of one-celled ovary, or non-development of several carpels;
(7.) By reduplication of the cells of the ovary, or augmentation in the number of ovaries;
(8.) By departure of the ovary from the line of the radius or inter-radius;
(9.) By flowers being dimerous or hexamerous.

Symmetrical flowers occur more frequently than among the monocotyledons. Other exceptional forms will be noticed in their proper place.

The forms of *inflorescence* are very varied among the dicotyledons; we may have a spike, a *catkin*, a raceme, a capitulum, an *anthodium*, a simple or a *compound umbel*, a corymb, a *dichasium*, a cyme, a *scorpioid* or *helicoid cyme*. (The forms in italics do not occur among the monocotyledons, while among dicotyledons we never find the spadix, the panicle, or the compound inflorescence so characteristic of Gramineæ).

The *stems* of our native dicotyledonous plants are *herbaceous* (never a culm) or *woody*, forming a *trunk*. All our native trees (with the exception of the conifers), our shrubs and shrub-like plants, are dicotyledons.

The *leaves* of the dicotyledons may be either simple or compound. *All our native species with compound leaves are dicotyledons.*

The *root* consists usually of a strong, thick *primary root* (tap-root), with a number of much more delicate and slender *secondary roots*.

Dicotyledons occur in all parts of the world. There are over 80,000 species known.

The dicotyledonous type includes such a vast number of species, that we shall not proceed, as in the case of the monocotyledons, to divide them at once into orders, but for the sake of simplicity, into two *Groups*.

GROUP I. SYMPETALÆ.—*Corolla always present, conspicuous, with united petals.*

GROUP II. CHORIPETALÆ.—*Corolla usually present, small or conspicuous, but never with petals united.*

Group I.

SYMPETALÆ.

The *Sympetalæ*[1] have always two floral envelopes, the external green (calyx), the internal brightly coloured (corolla); the individual sepals frequently, the petals always, united or coherent. Both whorls are either four or five lobed. Only one whorl of stamens is present; its members (2, 4, 5, 8, 10, never numerous) usually opposite the sepals, seldom opposite the petals (primrose). The stamens are frequently adnate to the corolla (*Corolliflorœ*), rarely, like the corolla, arising from the receptacle (Heaths). Ovary usually composed of as many carpels as there are sepals; when fewer, mostly two (Fig. 180). Ovary occasionally composed of four divisions, with a common style. Several or many separate ovaries in one flower never occur.—[35,000.]

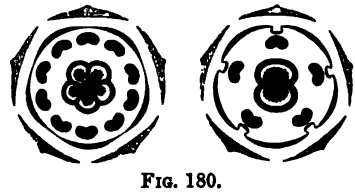


FIG. 180.
Sympetalous dicotyledons, with ovaries of two and five carpels.

KEY TO ORDERS OF SYMPETALÆ.[2]

I. Fewer carpels than sepals.

A. Ovary superior.

a. Ovary single-celled, single-seeded, . . 1. PLUMBAGINES.

b. Ovary single-celled, several-seeded, or consisting of four nutlets, each single-seeded.

* Ovary single, two-celled, several-seeded.

1. Corolla regular.

a. Leaves opposite, . . . 2. CONTORTÆ.

b. Leaves alternate, . . . 3. TUBIFLORÆ.

2. Corolla symmetrical, . . . 4. PERSONATÆ.

* * Ovary, four separate nutlets, each single-seeded, ... 5. NUCULIFERÆ.

B. Ovary inferior or half inferior.

a. Ovary several-celled and several-seeded.

* Flowers mostly unisexual, stamens partly united, ... 6. CUCURBITACEÆ.

* * Flowers hermaphrodite, stamens free.

1. Stamens adnate to calyx, . . 7. CAMPANULACEÆ.

2. Stamens adnate to corolla, . . 8. CAPRIFOLIACEÆ.

b. Ovary single-celled and single-seeded, . 9. AGGREGATÆ.

[1] Greek, *syn*, together; *petalon*, a petal.

[2] Comp. Table II., "General View of the Sympetalæ," at the end of the book.

II. Carpels of the same number as the sepals.

A. Ovary single-celled, flower corollifloral, . . 10. PRIMULINÆ.
B. Ovary several-celled, flower thalamifloral, . . 11. BICORNES.

I.

PLUMBAGINES.[1]

The *Plumbaginaceæ* (thrifts and plantains) are sympetalous dicotyledons, with one-celled, one-seeded, superior ovary, which later forms a capsule or achene. Corolla four or five lobed, often deeply cleft, inconspicuous, usually dry and membranous. Stamens four or five, alternating with or opposite to the petals. Flowers hermaphrodite (Fig. 181).

FIG. 181. *Plantago major.*

Leaves simple, lanceolate or broadly ovate; stem undeveloped, leaves often spreading on the ground. Flowers arranged in thick spikes or heads. The thrifts are perennial herbs, or half shrubs of the temperate regions. Represented by one order.

(13.) *Plantaginaceæ*.—Fruit a one-celled capsule with central seed; dehiscence circumscissile.—[210.]

We have several species of the genus *Plantago* (*Plantago major, media, lanceolata*, with four stamens and one style). The common thrift (*Armeria vulgaris*) is related. It has five stamens and five styles.

II.

CONTORTÆ.[2]

The *Contortæ* are sympetalous dicotyledons, with one-celled, many-seeded, or two-celled, few-seeded superior ovary, composed of two carpels. The calyx has its sepals united, four or five lobed. The corolla is regular, tetramerous or pentamerous, stamens two or five (rarely four), adnate to corolla. Styles, one or two. Æstivation mostly convoluted or twisted.

Trees, shrubs, or herbs with opposite, mostly decussate, leaves containing an acrid juice. Two orders.

(14.) *Gentianaceæ* (*Gentians*).—Floral envelopes five-lobed (rarely four-lobed), large, and conspicuously coloured (mostly

[1] From *plumbago*, the name of a plant. (The word is also dog-Latin for black-lead.)

[2] Latin, *contortus*, twisted.

blue), persistent when withered. Ovary one-celled, with parietal placentæ (Fig. 182), or two-celled, with seed in centre. Fruit usually a capsule.—[500.]

The Gentians are small herbs or shrubs, having mostly a smooth, hairless surface. Leaves simple, undivided, often with entire margin; no foot-stalk. Flowers single, and terminal or axillary (seldom in spikes, heads, or whorls). Root a rhizome or fibrous. Although the Gentians are found all over the world, their chief habitat is the colder regions. They are common in the Arctic regions, and below the snow-line on lofty mountains; their flowers are frequently very beautiful. Native species are bogbean (*Menyanthes trifoliata*), *Erythræa*, &c.

FIG. 182.
Gentian (*Gentiana Pneumonanthe*).

(15.) *Oleaceæ*.—Floral envelopes four-lobed, mostly small or medium sized, seldom absent (ash); stamens two, opposite the sepals. Ovary two-celled, each cell two-seeded; one style. Fruit a capsule, nut, or berry (Fig. 183).—[280.]

The *Oleaceæ* are trees or shrubs with opposite leaves, simple entire or impari-pinnate, and flowers in compound clusters. They grow chiefly in dry parts of the Temperate Zones in both hemispheres, also in warmer regions. They are specially abundant along the shores of the Mediterranean. The most familiar species are the olive (*Olea Europæa*) in Southern Europe; the privet (*Ligustrum vulgare*, leaves simple, flowers white, berries black); the syringa (*Syringa vulgaris* and *S. Persica*, leaves simple (Fig. 52), flowers lilac or white, fruit a dry brownish capsule); and the ash (*Fraxinus excelsior*), leaves impari-pinnate, floral envelopes dry or absent; fruit a winged nut.

FIG. 183.
Syringa vulgaris.

III.

TUBIFLORÆ.[1]

The *Tubiflorœ* are sympetalous dicotyledons, with two-celled, few or many-seeded superior ovary, composed of two carpels. Calyx free, sepals united, calyx five-lobed; corolla regular, five-lobed; stamens five, adnate to corolla, alternating with the petals. Style one. Fruit, a capsule or berry.

Herbs, half-shrubs, shrubs, or trees, with scattered or alternate, never opposite, leaves. Two orders in this country.

[1] Latin, *tubus*, a tube; *flos*, a flower.

(16.) *Convolvulaceæ* (*Bindweeds*).—Corolla tubular or funnel-shaped, five-plaited, convoluted or twisted in the bud; calyx often large, persistent; ovary two or four-celled, with one or two seeds in each cell. The ovary stands on a thick, yellowish cushion-like disk, which partly surrounds it at its base. Fruit a few-seeded capsule (Fig. 184; comp. also Fig. 79).—[800.]

FIG. 184. Bindweed (*Calystegia sepium*).

The bindweeds are herbs or shrubs, mostly with twining stems containing a milky juice; leaves scattered, simple, palmate, or pinnate; flowers large, axillary or terminal. The bindweeds are very numerous in the Tropics, common in the Temperate Zones, entirely unknown in the Arctic regions. Bearbind (*Calystegia sepium*) and bindweed (*Convolvulus arvensis*, Fig. 79) are our representative species. The tubers of *Batatas edulis* ("sweet potatoes") are used as food in the Tropics. A parasitic species, dodder (*Cuscuta*), infests our flax and clover.

(17.) *Solanaceæ* (*the Nightshades*).—Corolla tubular or funnel-shaped, five-plaited in the bud, five-toothed. Calyx herbaceous, persistent, and frequently altered after flowering. Ovary composed of two carpels, two-celled, each cell many-seeded. One style, stigma often bifid. There is no fleshy disk beneath the ovary. Fruit a two-valved capsule, or a berry; placentæ very thick, often fleshy, bearing numerous seeds (Fig. 185).—[1250.]

FIG. 185. Henbane (*Hyoscyamus Niger*).

The nightshades are herbs, shrubs, or trees with compound leaves, and flowers either axillary or terminal. They are most common and most beautiful in the Tropics, especially in America, but they are also known in the Temperate Zones of both hemispheres. Many are very poisonous (narcotic); many are used in medicine. The fruits and tubers of some species are used as food, *e.g.*, the tomato, which is the fruit of *Lycopersicum esculentum*, and the potato, which is the tuber of *Solanum tuberosum*. *Atropa Belladonna* (deadly nightshade), and *Hyoscyamus niger* (henbane) are indigenous. *Datura Stramonium* (the thorn-apple) is introduced. Of foreign species we may specially note the capsicums (*Capsicum annuum* and *C. baccatum*, or cayenne pepper), and the tobacco plant (*Nicotiana tabacum*).

IV.

PERSONATÆ.

The *Personatæ*[1] are sympetalous dicotyledons with two-celled, superior, many-seeded, rarely few-seeded, ovary, composed

[1] Latin, *personatus*, masked; *persona*, a mask.

of two carpels; calyx free with united sepals, four or five lobed, usually somewhat labiate. Corolla five-lobed, and decidedly bilabiate, ringent or personate (Fig. 87); the flower irregular but symmetrical (Fig. 186). When the flower is personate, it is sometimes spurred (Fig. 187, I. II.). Very rarely the corolla is not labiate, but four-lobed and regular (Fig. 84), or five-lobed (Fig. 187, V., VI.), and only slightly irregular. Stamens usually four, two long and two short (the uppermost absent, Fig. 186). Sometimes five are present (Fig. 187, V.), or two (Fig. 84). Filaments adnate to corolla. Fruit a two-celled, two-valved capsule (Fig. 187, III., IV., VII.). Style one; stigma bifid.—[1900.]

FIG. 186.
Frog's-mouth (*Antirrhinum majus*).

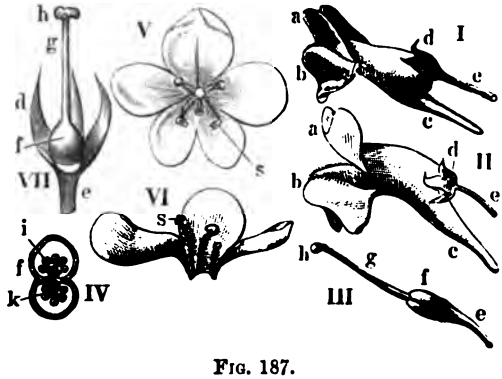


FIG. 187.

Personatæ.—I., IV. Toadflax (*Linaria vulgaris*). I. Flower, nat. size; II. Same, under-lip bent back; III. Ovary, twice enlarged; IV. Same in cross section, six times enlarged; V., VII. Mullein (*Verbascum Thapsus*); V. Flower, nat. size; VI. Same, longitudinal section; VII. Ovary, twice enlarged; *e* Flower-stalk; *d*. Calyx; *a* Upper lip; *b* Lower lip; *c* Spur; *s* Stamens; *f* Ovary; *g* Style; *h* Stigma; *i* Ovules; *k* Placenta.

Herbs, rarely shrub-like plants or shrubs. Stem cylindrical, more rarely quadrangular. Leaves opposite, in whorls or scattered, simple or cleft, sessile or stalked. Flowers axillary, in whorls or in spikes, always hermaphrodite.

(18.) *Personatæ* (*Scrophulariaceæ*), a very large order, of which representative genera are found at the Equator as well as at the Poles. The following are the chief indigenous families:—

I. Flowers flat, rotate, almost regular, rim four or five-toothed.

A. Rim five-toothed, stamens five, . . . 1. VERBASCEÆ.
B. Rim four-toothed, stamens two, . . . 2. VERONICEÆ.

II. Corolla campanulate, labiate, ringent or personate.

A. Tube of corolla spurred or knobbed, . . 3. ANTIRRHINEÆ.
B. Tube of corolla without spur or knob.
a. With green foliage leaves.
* Corolla campanulate, slightly labiate, rim four or five cleft.
1. Rim of corolla bilabiate, . . 4. SCROPHULARIÆ.
2. Rim of corolla not labiate, only slightly four-lobed, . . 5. DIGITALEÆ.
** Corolla ringent, with large casque-shaped upper lip, . . . 6. RHINANTHEÆ.
b. Parasitic plants with brown scales instead of leaves, ... 7. OROBANCHEÆ.

1. *Verbasceæ* (vervains), represented in this country by the large vervain genus (*Verbascum*), mostly yellow-flowering species (Fig. 187, V.-VII.). 2. *Veroniceæ* (the veronicas), distinguished by having blue flowers (Fig. 84). 3. *Antirrhineæ* (snapdragons), the most important species are *Antirrhinum* (snapdragon, Fig. 87) and *Linaria* (toadflax, Fig. 187, I.-IV.). 4. *Scrophulariæ*, indigenous genus *Scrophularia*, with greenish brown or greenish yellow inconspicuous flowers. 5. *Digitaleæ* (foxgloves), the foxglove genus (*Digitalis*). 6. *Rhinantheæ*, plants of this order are remarkable for turning black when dried. Flowers conspicuous, bluish red, purple, yellow, &c. *Melampyrum*, *Pedicularis* (louse-wort), *Rhinanthus* (yellow-rattle). *Euphrasia* (eye-bright). These are mostly semi-parasitic on the roots of other plants. 7. *Orobancheæ* (broom-rapes), parasitic plants of brownish colour, with small, scale-like leaves, bilabiate corolla and one-celled ovary with parietal placentæ. Illustrative genus *Orobanche*, with many species very difficult to distinguish from one another, often infesting cultivated plants.

V.

NUCULIFERÆ.[1]

The *Nuculiferæ* are sympetalous dicotyledons with superior ovary, divided into four fruitlets having a common style. Each fruitlet is called a nucule; the nucules are elongated and rounded or angular in shape; they each contain one seed. The corolla

[1] Latin, *nuculus*, a nutlet (dim. of nux); *fero*, I bear.

is five-lobed, regular or irregular; so also is the calyx. Stamens five or four, rarely two; adnate to petals, usually alternating with them. Flowers always hermaphrodite.

Herbs or shrub-like plants, frequently very hairy. Leaves opposite or scattered. Two orders.

FIG. 188.
Dead-nettle (*Lamium album*).

(19.) *Labiatæ*.—Corolla distinctly symmetrical (Fig. 188), bilabiate; upper lip large, mostly casque-shaped, concealing the stamens and style (Fig. 189, *o*); lower lip having several teeth, flatter than the upper lip, without spur-like prominence. Tube of corolla long, rounded, often inflated at the base. Calyx either five-toothed (Fig. 189, I.), or labiate (V.). Stamens usually four, two long and two short. Style basilar, *i.e.*, arising from between the lobes of the ovary; stigma double, the two parts unequal in length.—[2600.]

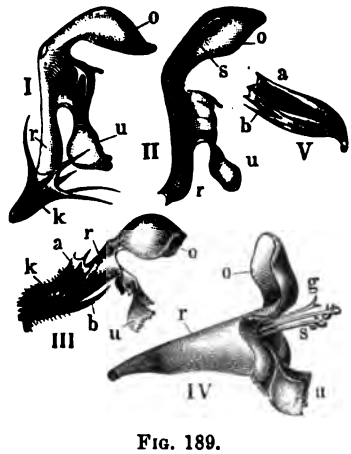


FIG. 189.

Labiatæ.—I. II. Dead-nettle (*Lamium album*). I. Flower, nat. size; II. Same, longitudinal section; III.-V. Self-heal (*Prunella vulgaris*); III. Flower viewed from the side, twice nat. size; IV. Corolla, upper lip bent back, thrice nat. size; V. Calyx, three times enlarged; *k* Calyx; *a* Upper lip of same; *b* Lower lip; *o* Upper lip of corolla; *u* Lower lip of same; *r* Tube of corolla; *s* Stamens; *g* Style.

The order *Labiatæ* contains many species, and is distinguished from all others by the bilabiate, bilaterally symmetrical, united corolla, and the peculiar ovary with four nutlets. Its members are mostly herbs or shrub-like plants, seldom true shrubs, with quadrangular, hollow stems, with swollen nodes. The leaves are decussate, simple or indented. Flowers in spikes, tufts, or whorls (Fig. 102). The Labiatæ are most plentifully represented in the warm Temperate Zones, but are met with all over the world. They are specially numerous along the Mediterranean coast, from Portugal to Asia Minor; the flora of Mexico is also distinguished for the large number of Labiatæ it embraces.

The *Labiatæ* are divided into the following families :—

I. Rim of corolla not labiate, almost regular, four or five lobed; tube shorter than or of equal length with the calyx; stamens two or four, ... 1. MENTHOIDEÆ.

II. Corolla labiate.
  A. Upper lip present, large or of medium size.
    a. Stamens two ; upper lip very large, . . . 2. MONARDEÆ.
    b. Stamens four ; upper lip large or of medium size.
      * Filaments *separate*, bending from or towards each other above, ... 3. SATUREÏNEÆ.
      ** Filaments running *parallel* with each other under the lower lip.
        1. *Upper* (or inner) stamens *shorter* than the *lower* (or outer).
          † Calyx bilabiate ; upper lip entire or three-toothed, ... 4. SCUTELLARINEÆ.
          †† Calyx straight or slanting, three to ten toothed, or almost untoothed, . . 5. STACHYDEÆ.
        2. *Upper* stamens *longer* than the under, . 6. NEPETEÆ.
  B. Corolla one-lipped (upper lip very small), . . 7. AJUGEÆ.

From the above list we see that in the Labiatæ the size of the upper lip is subject to great variation. It may be totally absent, small, middle-sized, or large. A noteworthy fact is that there is a relationship between the size of the upper lip and the *geographical distribution* (Figs. 190-193). In Western Europe (Spain and Portugal) the *Ajugeæ*, which have scarcely any upper lip, prevail ; in the south of France and Western Italy the *Satureïneæ*, also with small upper lip (Fig. 191) ; in Germany, Switzerland, and North Italy the *Stachydeæ*, with moderately well-developed upper lip (Fig. 192), in Southern Russia, Asia Minor, and Persia, the *Phlomideæ* (Fig. 193), with very large casque-shaped upper lip.

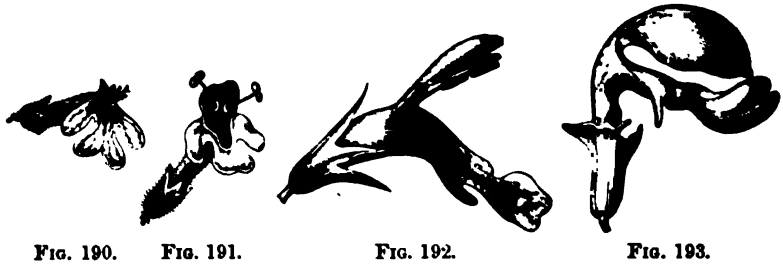


FIG. 190. FIG. 191. FIG. 192. FIG. 193.

Flowers of Labiatæ. Fig. 190.—*Ajuga reptans*. Fig. 191.—*Origanum vulgare*. Fig. 192.—*Galeopsis versicolor* (hemp-nettle). Fig. 193.—*Phlomis Roeseliana*, nat. size. Figs. 190-192 somewhat enlarged.

The following are some of the indigenous genera of *Labiatæ* :—

(1.) *The Mints* (*Menthoïdeæ*).—Of these *mint* (*Mentha*), a genus comprehending many species, and *Lycopus*. (2.) *Monardeæ*.—The *sage* germs (*Salvia*), including two wild species. (3.) *Satureïneæ*.—*Marjoram origanum* (Fig. 191), *thyme* (*Thymus*), &c. (4.) *Scutellarineæ*.—*Scutellaria* and *Prunella* (comp. Fig. 189, III. V.) (5.)

Stachydeæ.—The *dead-nettle* order (*Lamium*, Fig. 102 and Fig. 189, I. II.), *hemp-nettle* (*Galeopsis*, Fig. 192), *wound-wort*, *Stachys*, &c. (6.) The *Nepeteæ* or *Cat-mints.*—Catmint (*Nepeta*) and ground ivy (*Glechoma*). (7.) *Ajugeæ.*—*Ajuga* and wood-sage (*Teucrium*).

(20.) *Boraginaceæ* (*the Borage family*).—Flower regular or very slightly symmetrical, never labiate. Calyx free, five-lobed, sepals united, corolla five-lobed, prolonged below into a tube. Stamens five, sometimes concealed by processes of the corolla. The four lobes of the ovary united in pairs. Fruit four nutlets (Fig. 194).—[1200.]

Fig. 194. Lung-wort (*Pulmonaria officinalis*).

The Boraginaceæ are herbs or shrubs whose leaves and stems are usually covered with stiff, bristly hairs. The stem is cylindrical, the leaves simple, alternate. The Boraginaceæ are found in the warm and in the temperate zones. Home genera are hound's-tongue (*Cynoglossum*), borage (*Borago*), *Anchusa*, *Symphytum*, *Echium*, *Pulmonaria* (lung-wort), *Lithospermum*, *Myosotis* (forget-me-not), &c.

VI.

CUCURBITACEÆ.[1]

The *Cucurbitaceæ* (gourds) are sympetalous dicotyledons with inferior three-celled, many-seeded ovary; flowers monœcious or diœcious; stamens united in two pairs, the fifth remaining free (Fig. 195). Calyx superior, five-lobed; corolla also five-lobed. Anthers twisted. Fruit a pepo, three-celled, many-seeded (Fig. 132). Stigmas three, very thick.

(21.) *Cucurbitaceæ*, the cucumber order.—Annual, more rarely perennial plants, with cylindrical branched creeping stems, and scattered simple or palmate leaves—the leaves often very large. The stems are frequently prolonged into much-twisted tendrils.—[500.]

Fig. 194. Gourd (*Cucurbita Pepo*).—Represented as hermaphrodite.

The *Cucurbitaceæ* is mainly a tropical order, having a few representatives in temperate regions, none in Arctic. The succulent fruits are much esteemed as an article of food, either fresh or preserved, *e.g.*, the

[1] New. Lat., *pepo*, a gourd; *fero*, I bear.

gourd (*Cucurbita Pepo*, originally a native of the East), the cucumber (*Cucumis sativus*), the melon (*C. Melo*), and the water melon (*C. citrullus*). The snake-gourd (*Trichosanthes anguina*) is much prized by the natives of the Tropics ; its hard rind is utilised to form various sorts of vessels. The poisonous bryony (*Bryonia dioïca*) is the only indigenous species.

VII.

CAMPANULACEÆ.[1]

The *Campanulaceæ* (*Bell-flowers*) are sympetalous dicotyledons with inferior or median ovary, two-celled, many-seeded. Flowers hermaphrodite, regular. Stamens free ; fruit a capsule.

(22.) *Campanulaceæ*.—Calyx half or wholly superior, four or five-lobed, like the corolla. Ovary consisting of two, three, or several carpels (Fig. 196). One style. Stigmas as many as cells of the ovary, usually three. —[500.]

FIG. 196. Campanula (*Campanula patula*).

Herbs, rarely shrubs. Stem cylindrical, leaves alternate, rarely opposite, simple or lobed, sessile or stalked. The *Campanulaceæ* are common in the temperate and colder regions, being found even on lofty mountains ; they are not so characteristic of the tropical flora. Most species are found in Europe, Asia, and North America. *Jasione*, *Phyteuma*, and the various species of *Campanula* (hare-bell, Canterbury bell, &c.) are indigenous to this country.

VIII.

CAPRIFOLIACEÆ.[2]

The *Caprifoliaceæ* are sympetalous dicotyledons with inferior, several-celled, several-seeded ovary, and hermaphrodite flowers with stamens adherent to the corolla-tube (the point of attachment often very low down). Flowers four or five lobed, regular or bilaterally symmetrical ; fruit a berry, rarely a capsule.

(23.) *Caprifoliaceæ*.—Calyx epigynous, like the corolla four or five lobed. Ovary composed of three or four carpels, three or four celled, each cell two-seeded (Fig. 197), or one-seeded, very rarely several-seeded.

[1] Latin, *campanula*, a bell. [2] Latin, *caper*, a goat ; *folium*, a leaf.

Shrubs or low trees (sometimes shrub-like climbing plants), with opposite simple, entire, or lobed leaves. Flowers single or in pairs, also in simple or compound clusters. A small group found in the temperate regions of both hemispheres. Native genera—*Adoxa*, *Sambucus* (the elder), *Viburnum* (guelder rose), *Lonicera* (honeysuckle, several species). A common garden-plant is the snowberry (*Symphoricarpus racemosus*).

FIG. 197. Honeysuckle (*Lonicera Xylosteum*).

Related to the Caprifoliaceæ is the large order *Rubiaceæ* (*Madders*), with regular four or five-lobed flowers, and inferior two-celled ovary. Of the four hundred species known, only a few are native to this country; these are mostly low herbs with whorled sessile leaves, and small flowers—*Galium*, *Asperula* (wood-ruff). The order is only typically developed in the Tropics, where many species attain the height of trees. Coffee is made from the berry of the tropical genus *Coffea*, quinine from the bark of the South American *Cinchona*.

IX.

AGGREGATÆ.[1]

The *Aggregatæ* are sympetalous dicotyledons with inferior one-celled, one-seeded ovary, from whose summit arise the calyx (mostly hairy) and corolla. Petals and stamens of equal number, always four or five. Inflorescence aggregated into a dense head or capitulum surrounded by an involucre, whence the name given above. The following two orders are important:—

(24.) The *Dipsaceæ* or *Scabious Order*.—Calyx apparently double, having an epicalyx or involucel—both tubular; corolla arising from the throat of the calyx, tubular, five or four lobed, occasionally almost labiate; stamens four, alternating with the lobes of the corolla, sometimes of unequal length. Style one, longer than the corolla, stigma often short, bifid. Achene indehiscent, surrounded by the persistent involucel, and surmounted by the persistent calyx, brownish in colour (Fig. 198).

FIG. 198. *Succisa pratensis.*

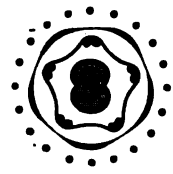


FIG. 199. *Cirsium oleraceum.*

Herbs with opposite simple, pinnate or bipinnate leaves. The flowers, always hermaphrodite, grow in compact heads, surrounded by

[1] Latin, *aggregatus*, past participle of *aggrego*, I heap up.

an involucre of bracts. Indigenous to the Temperate Zones. Home genera, *Dipsacus* (including teazle (*D. Fullonum*), whose dried capitula are used to comb up the nap on cloth), and *Scabiosa*, including various species of scabious.—[120.]

(25.) *Compositæ.*—Calyx[1] represented by simple bristles or feathered hairs (*Pappus*, comp. Fig. 74 and Fig. 96, V.), which often persist and crown the fruit; corolla either regular, tubular, and five-lobed (Fig. 74), or somewhat irregular, and tubular (Fig. 85), or ligulate (Fig. 83). Stamens five, attached to tubular corolla, and alternating with its lobes (Fig. 199). Filaments free, but anthers united into a tube around the style. Style one, stigma bifid.—[10,000 species.]

FIG. 200.
Capitulum of thistle (*Cirsium oleraceum*); nat. size.

Inflorescence a capitulum or anthodium, consisting either of tubular florets (Fig. 200), or of florets tubular in the centre, ligulate at the circumference (comp. Fig. 107, II.), or of ligulate florets alone (dandelion). The external florets are often either female or neuter. Each capitulum is surrounded by a number of imbricated bracts, forming an involucre. The capitula either grow singly at the end of a long flower-stalk (daisy), or often in a corymb (Fig. 119).

The Compositæ are herbs or under-shrubs (rarely shrubs), annual or perennial, with fibrous or tuberous roots. The leaves are alternate, opposite, or whorled, simple or compound, the upper leaves usually smaller than the lower. The Compositæ is the largest of all the natural orders, embracing about one-ninth of all the known species of plants. Members of the order are to be found in all parts of the world, from the Equator to the extreme limit of Polar vegetation. The following are our most important native families:—

[1] The late appearance in development of the pappus, and its epidermic character, are frequently urged against its being regarded as calyx.—Tr.

I. Capitula, either composed entirely of tubular florets, or centrally of tubular, peripherally of ligulate florets. Juice watery (*Tubuliflorœ*).

A. Style not thickened, cylindrical or club-shaped at the apex.

a. Style warty, or slightly hairy at the apex.

* Style club-shaped, . . . 1. EUPATORIÆ.

** Style linear, ... 2. ASTEROIDÆ.

b. Style linear and cylindrical, blunt at the apex, and covered with long hairs.

* Anthers without appendages at the base.

1. Pappus either awanting or stiff, like bristles crowning the fruit.

† Leaves usually opposite, anthers black, . . 3. HELIANTHEÆ.

†† Leaves usually alternate, anthers yellow, . . 4. ANTHEMIDEÆ.

2. Pappus downy, . . . 5. SENECIONEÆ.

** Anthers with appendages at the base, . . 6. GNAPHALIÆ.

B. Style much thickened at the apex, and there very hairy, ... 7. CYNAREÆ.

II. Florets all ligulate. Juice milky (*Liguliflorœ*).

A. Pappus entirely absent, involucre composed of from five to eight bracts, ... 8. LAPSANEÆ.

B. Pappus present, involucre composed of an indefinite number of bracts.

a. Pappus short, bristly; the bristles flattened, blunt at the apex, free or slightly united, ... 9. CICHOREÆ.

b. Pappus feathery or hairy.

* Pappus feathery (at least on the central florets); the hairs rarely simple at the apex, divided at the base.

1. Each whorl of pappus hairs unequal in length; receptacle naked, or covered with fine filaments, ... 10. LEONTODONTEÆ.

2. Each whorl of pappus hairs of equal length; receptacle naked, 11. TRAGOPOGONEÆ.

** Pappus hair-like, hairs always simple.

1. Achene flattened, . 12. LACTUCEÆ.

2. Achene cylindrical or angular, not flat, . 13. HIERACEÆ.

The following are typical representatives of these orders :—1. *Eupatoriæ—Eupatorium cannabinum*, Fig. 74 (hemp-agrimony), *Tussilago Farfara* (coltsfoot), *Petasites officinalis*. 2. *Asteroideæ* (*the asters*).—*Aster sinensis* (the common aster of cultivation), *Bellis perennis* (the daisy), and *Inula* (elecampane). 3. *Heliantheæ* (sunflowers).—*Helianthus annuus* (the common sunflower, a native of America); *Bidens* (bur-marigold), a native of this country). 4. *Anthemideæ* (the camomiles).—*Artemisia* (wormwood), *Achillea*, Fig. 119 (milfoil), *Anthemis*, *Matricaria Chamomilla* (the camomile), *Tanacetum vulgare* (tansy), *Chrysanthemum*. 5. *Senecioneæ* (the groundsel).—*Arnica montana*, *Senecio* (groundsel). 6. *Gnaphaliæ*.—*Filago*, *Gnaphalium*, *Helichrysum arenarium*. All plants of this family are remarkable for the thick, ragged white or grey hairs by which they are covered (the various species are classed together as *Immortelles*). 7. *Cynareæ* (the thistles).—*Cirsium* (fuller's thistle), *Carduus* (common thistle), *Arctium* (burdock), *Centaurea* (cornflower). 8. *Lapsaneæ*.—*Lapsana*, *Arnoseris* (lamb's succory). 9. *Cichoriæ*.—*Cichorium Intybus* (common chicory), and *C. Endivia* (salad endive). 10. *Leontodonteæ* (*dandelions*).—*Leontodon* (yellow hawkbit), *Picris*. 11. *Tragopogoneæ* (the goat's-beard).—*Tragopogon* (goat's-beard). 12. *Lactuceæ* (lettuces), *Lactuca*. —*Taraxacum officinale* (common dandelion), *Sonchus* (sow-thistle) (Fig. 200). 13. *Hieraciæ* (hawkweed).—Two genera, including numerous species, *Crepis* (hawk's-beard), and *Hieracium* (hawkweed).

X.

PRIMULINÆ.

The *Primulinæ* are sympetalous dicotyledons which have carpels, sepals, and petals isomerous (5). The ovary is one-celled and many-seeded, the ovules attached to a central placenta. Stamens five, adnate to corolla, and superposed to its lobes. Fruit a capsule (Fig. 201, Fig. 99, III.). One order.

FIG. 201. Primrose (*Primula elatior*).

(26.) *Primulaceæ* (*the Primrose Order*).—Herbs, mostly with simple persistent short stem; leaves simple, mostly entire, growing close to the ground; flower-stalk unbranched, bearing flowers in a terminal umbel. In other cases the flowers stand singly, or in clusters, &c. Flowers always hermaphrodite.

The Primulaceæ belong principally to the flora of the north temperate regions of both hemispheres, partly also to that of high mountains. Many species are cultivated. Native genera: — *Primula officinalis* (the common primrose), *P. elatior* (oxlip), *Trientalis europæa*, *Hottonia palustris* (bog primrose), *Lysimachia*, *Anagallis*

arvensis. The auricula (*Primula auricula*), the Chinese primrose (*Primula sinensis*), and the cyclamen (*Cyclamen europæum* and *C. persicum*) are favourite garden plants.

XI.

BICORNES.[1]

The *Bicornes*, or heaths, are sympetalous dicotyledons with epigynous stamens. Carpels (four and five) as many as the lobes of calyx or corolla. Ovary four or five-celled, many-seeded; seeds not attached to a central placenta. Fruit a berry or a capsule. Two orders.

FIG. 202.
Bilberry (*Vaccinium Myrtillus*).

(27.) *Vaccinieæ, or Whortleberries.* — Calyx adherent to the ovary, four or five-lobed; sepals, like the petals, united; petals deciduous. Stamens twice as many as petals, arranged in *one* whorl epigynous. Ovary inferior, cells four or five; one style. At the summit of the ovary is a thick fleshy disk (Fig. 202); fruit a berry.—[50.]

The *Vaccinieæ* are gregarious plants of the Northern Hemisphere, growing only in the temperate and colder regions. They are found on barren, sandy, or turfy moors. All plants of this order are shrubs, many of them only a few centimetres high (Fig. 203). The leaves are small and simple, often thick and leathery, usually evergreen. They spring from the branches at irregular intervals. Flowers mostly reddish; berries red or dark purple. Native species—*Vaccinium Oxycoccus* (cranberry), *V. Myrtillus* (bilberry), *V. uliginosum* (black whortleberry), and *V. Vitis-Idæa* (red whortleberry).

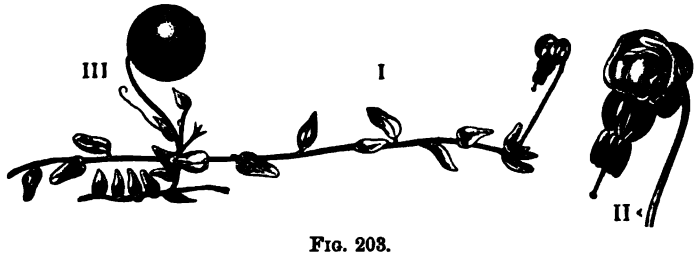


FIG. 203.
Cranberry (*Vaccinium Oxycoccus*).—I. Plant, nat. size; II. Flower, four times enlarged; III. Fruit, nat. size.

(28.) *Ericaceæ* (the heaths).—Calyx and corolla each united,

[1] Latin, *bis*, twice, *cornu*, a horn; because the stamens have two hornlike appendages at the base of the anthers.

four or five lobed. Below the ovary the receptacle is widened so as to form a ring, from which arises the persistent corolla. Stamens arising from the expanded thalamus, as many or twice as many as the petals, in both cases forming only one whorl. Cells of the ovary four or five, opposite the petals; style one. Fruit a capsule or berry (Fig. 204).—[1150.]

The *Ericaceæ* are shrub-like plants, shrubs, or trees (*e.g.*, *Arbutus Unedo*, a species indigenous to South Europe and Asia Minor), with scattered or whorled, leathery, often needle-shaped, leaves, single or clustered flowers, and mostly perennial roots. They are confined chiefly to the northern temperate regions and South Africa; in New Holland they are represented by the Epacridaceæ, an allied sub-order. The heaths, properly so-called, are the most important. The name "heath" is given to large tracts of country, corresponding in some degree to the Asiatic and South African steppes, when overgrown with *Calluna vulgaris*, the common heath. Familiar also is the bell-heath (*Erica Tetralix*, Fig. 77), which grows in damp, turfy spots. In Lapland the genus *Erica* is represented by such numerous and varied species, that it has not yet been found possible to exhaust them: every valley, every mountain, possesses some peculiar endemic variety. The fact of there being so many species of *Erica* in Lapland is all the more remarkable, seeing that elsewhere throughout the whole Northern Hemisphere we find but a few species prevailing everywhere.

FIG. 204. Heath (*Andromeda polifolia*).

Other noteworthy native plants of the order Ericaceæ are *Arctostaphylos Uva-Ursi*, *Andromeda*, *Pyrola* (the winter-green), and *Monotropa* (Fig. 6, *a*), a degenerate root-parasite.

Group II.

CHORIPETALÆ.[1]

The *Choripetalæ* have either the floral envelopes almost entirely absent, or only one present, or normally both present. If only one is present (perianth), its parts may be either free or united; if two are present, the petals of the inner whorl (corolla) are *always free*. The stamens are arranged either in one, or, as is more usual, in two whorls (*several* whorls may arise through radial reduplication), the first or outer whorl being mostly opposite the sepals, the second or inner opposite the petals. The number of stamens varies from one to many; they are not united to the

[1] Greek, *choris*, free, not united; *petalon*, a petal.

corolla, but are inserted on the receptacle or on the rim of the calyx (Thalamifloræ and Calycifloræ). The ovary usually consists of as many carpels as there are sepals (four or five), but it may consist of more or less. In many flowers there are several or many ovaries, each composed of a single carpel.—[45,000.]

KEY TO ORDERS OF CHORIPETALÆ.[1]

I. Flowers inconspicuous, floral envelopes *entirely awanting* or small, never brightly coloured, *never double*. Ovary one-celled, very rarely three-celled; flowers rarely hermaphrodite, inflorescence usually a catkin,

A. Flowers unisexual, ♂ in catkins, . . . } 1. AMENTACEÆ or CATKIN-BEARERS.

B. Flowers hermaphrodite or unisexual, ♂ not in catkins, ... } 2. URTICINÆ or NETTLES.

II. Floral envelopes large, double or single, the latter always in the form of a perianth (if the perianth is greenish, the flowers do not form catkins, and are ☿ flowers with single-seeded ovaries).

A. Seed on central placentæ, ovary one-celled, always single. Stamens one to ten. Fruit a nut or capsule, ... 3. CENTROSPERMÆ.

B. Seed not as in the latter class. Ovary mostly several-celled (if one-celled it forms a berry, or there are several in one flower).

a. Flower a *simple perianth*, with *united parts*, 4. MONOCHLAMYDEÆ.

b. Floral envelopes *double*, or forming a perianth with several petals.

* Ovary inferior.

1. Calyx almost absent, flowers in umbels, 5. UMBELLIFLORÆ.

2. Calyx present, flowers not in umbels.

a. Fruit a capsule or berry.

† Calyx and corolla pent- or tetr-amerous, in the latter case having many stamens, ... 6. SAXIFRAGINÆ.

†† Calyx and corolla di- or tetr-amerous; stamens four or eight, . 7. MYRTIFLORÆ (in part).

β. Fruit a few-seeded pome, . . . 8. ROSIFLORÆ (in part).

** Ovary superior.

1. Stamens inserted on the throat of the calyx.

[1] Compare Tables III. and IV., "General View of the most important Choripetalæ,"—A and B, at the end of the book.

α. Flowers regular.	
† Ovary one, two-celled, several-seeded, ...	7. MYRTIFLORÆ.
†† Ovary one, one-celled and one-seeded, or several one-seeded cells,	8. ROSIFLORÆ.
β. Flowers symmetrical (Papilionaceæ),	9. LEGUMINOSÆ.
2. Stamens inserted on the ovary.	
α. Ovary one, composed of one carpel, or several, each one-seeded, . .	10. POLYCARPICÆ.
β. Ovary one, composed of from two to many carpels, one to five celled; cells two or many-seeded.	
† Petals four or numerous, . .	11. RHŒADINÆ.
†† Petals five.	
⊙ Ovary one-celled, . .	12. CISTIFLORÆ.
⊙⊙ Ovary several-celled.	
♃ Stamens numerous, . .	13. COLUMNIFERÆ.
♃ ♃ Stamens five, seven, eight, or ten.	
□ Stamens united, .	14. GRUINALES.
❑❑ Stamens free.	
↕ Whorl of stamens decamerous, or seven eight members fully developed, . .	15. ÆSCULINÆ or HORSE CHESTNUTS.
↕ ↕ Whorls of stamens pentamerous, all the members fully developed, . .	16. FRANGULINÆ.

I.

AMENTACEÆ.[1]

The *Amentaceæ* (catkin-bearers) are choripetalous dicotyledons, with very simple, inconspicuous flowers. Bracts absent, or reduced to a mere scale; calyx and corolla not to be distinguished. Flowers always unisexual, either monœcious or dicecious. The ♂ always in catkins (Fig. 205); externally only the scaly bracts are visible, under which lie the flowers, consisting only of stamens, either single or in groups. Ovary usually one-celled and two-seeded, rarely three-celled and six-seeded, or one-celled and many-seeded. Fruit an indehiscent or winged nut, in which only *one* seed is developed (the other ovules are suppressed), occasionally a two-valved, several-seeded capsule.

[1] Latin, *amentum*, a catkin.

The Amentaceæ are trees or shrubs with simple leaves. They are divided into three orders :—

(29.) *Betulaceæ* (*the Birch Order*).—Flowers monœcious. The ♂ quite without floral envelopes, or these only rudimentary ; stamens two to four, concealed beneath a stiff scale (bract, Fig. 206, 207, I.) ♀ flowers united to form a short rounded catkin (III.), every two or three enclosed by a bract (II.). Fruit a two-seeded winged nut, or a one-seeded nut, the base of which is surrounded by a leaf-like cup formed by the development of the bracts (hazel-nut).—[200.]

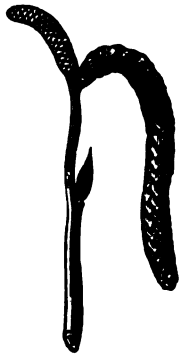


FIG. 205.
Male catkin of the birch (*Betula alba*), nat. size.

The Betulaceæ are trees or shrubs of the northern colder temperate regions, some species of which even pass up as far as the northern limits of vegetation (*Betula nana* or dwarf birch). Native species are the common birch (*Betula alba*), *Betula pubescens*, *Alnus glutinosa* (the alder), *Corylus Avellana* (hazel), and *Carpinus Betulus* (hornbeam). In Italy *Corylus tubulosa* (the filbert) is also found.

FIG. 206.
Flowers of hazel (*Corylus Avellana*).

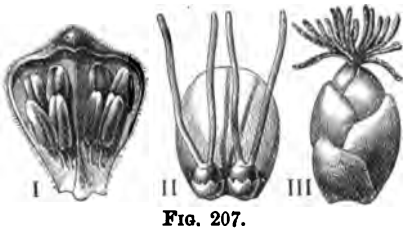


FIG. 207.
Hazel (*Corylus Avellana*). — I. Male flower. II. Female flower, eight times enlarged. III. ♀ catkins, four times enlarged.

(30.) *Cupuliferæ* (*the Oak Order*).—Flowers monœcious, ♂ flowers in catkins or clustered. Floral envelopes absent, or four to five lobed ; stamens five or ten (Fig. 209), adherent to the scales of the perianth. ♀ flowers ; ovary adnate to the united perianth, with three stigmas at the apex (Fig. 210). Ovary two to six celled, each cell one or two seeded. Fruit a nut, with only one cell developed and one seed (the rest abortive) ; base of the nut surrounded by a hard cup (*c*, Fig. 208), formed by development and enlargement of the bracts which, in the flower, encircled the ovary.—[200.]

The Cupuliferæ are indigenous to the Temperate Zones of both hemispheres, but are scantily represented in the region of the Equator. The

FIG. 208. FIG. 209. FIG. 210.

Oak (*Quercus Robur*). Fig. 208.—Fruit, nat. size. Fig. 209.—Floral diagrams. Fig. 210.—Two ♀ flowers, somewhat enlarged —*c* Cup, *d* Bract, *h* Perianth, *n* Stigmas.

order consists mostly of trees which grow together in large numbers, and form forests. It includes the oak genus (*Quercus*), containing many species; among others, our *common oak* (*Quercus Robur*), the *holm oak* (*Quercus Ilex*, with leathery evergreen leaves), plentiful in Italy and in the southern spurs of the Alps, and the *cork tree* (*Quercus Suber*, a native of Spain and North Africa), whose bark forms the cork of commerce. The Cupuliferæ also includes the genus beech (*Fagus*), one species of which (*Fagus sylvatica*, the *common beech*) is one of our most familiar forest trees. *Fagus ferruginea* is to the woods of North America what *Fagus sylvatica* is to ours. In Chili we have *F. obliqua*, and in Tierra del Fuego *F. antarctica* and *betuloïdes* forming extensive forests. The esculent chestnut also belongs to this order (*Castanea vesca*); it is a native of Southern Switzerland and Italy.

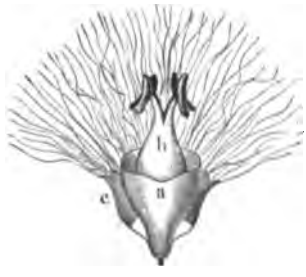


FIG. 211.

♀ flower of the black poplar (*Populus nigra*). *a* Cup-shaped development of the receptacle; *b* Ovary with two bifid stigmas; *c* Scaly bracts.

(31.) *Salicineæ* (*the Willow Order*) —Flowers dioecious. ♂ and ♀ flowers, both in catkins. Floral envelopes are absent in both sexes, their places being taken either by a fleshy protuberance (in the willows), or by a cup-like shell (the poplars, Fig. 211, *a*). ♂ flowers, stamens few (*e.g.*, two, Fig. 212, ♂), or many (as many as twenty-four); they are free or united by their filaments. ♀ flowers, each flower protected by a scaly bract (*c*, Fig. 211), the edge of which is so

much split up as to look like a fringe of hairs; ovary (*b*, Figs. 211, 212, ♀) one, free, many-seeded, seeds arranged in several rows. Style one, stigmas two, bifid. Fruit a two-valved capsule, seeds clothed with downy hairs. —[180:]

Fig. 212. *Salix caprea.*

Trees or shrubs of the temperate and colder regions. Native genera—the willow (*Salix*) and the poplar (*Populus*). The most important of the willow are the common willow-tree (*Salix fragilis*), the weeping willow (*S. babylonica*), the osier willow (*S. viminalis*), and goat-willow (*S. Caprea*). In Alpine and Arctic regions we find *S. Lapponum* (the Lapland willow) and *S. reticulata*, which only attain a height of a few centimetres. To the poplars belong—*Populus alba* (the white poplar), *P. tremula* (the aspen), *P. pyramidalis* (Lombardy poplar), and *P. nigra* (the black poplar).

II.

URTICINÆ.[1]

The *Urticinæ*, or nettles, are choripetalous dicotyledons with very simple, inconspicuous flowers. The floral envelopes are better developed than among flowers of the last order; the perianth consists of from four to six greenish scale-like parts. Flowers unisexual or ☿. Stamens usually of the same number as the teeth of the perianth, and placed opposite to these. Catkins with bracts are never found. Ovary mostly one-celled and one-seeded. Fruit an indehiscent or winged nut.

Trees, shrubs, or herbs with simple, frequently lobed, leaves. Two orders are important :—

(32.) *Ulmaceæ* (*the Elm Order*).—Flowers ☿ in scaly clusters or tufts; perianth simple, five to six lobed and campanulate; stamens as many as the lobes of the perianth, and placed opposite to these (Fig. 213). Ovary superior, one-celled, one-seeded; stigmas two. Fruit an indehiscent samara (Fig. 214).—[140.]

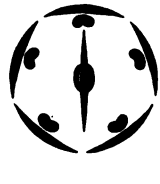


Fig. 213.

Fig. 214.

Fig. 213. — Elm (*Ulmus campestris* ♂). Fig. 214.—Samara of the elm (*Ulmus campestris*); nat. size.

The Ulmaceæ come in between the Betulaceæ and the Urticaceæ. They are trees or herbs, with alternate, simple leaves. *Ulmus campestris* (the common elm) and *U. montana* are native species. Related to the elms are the *Plataneæ* or plane-

[1] From Latin, *urticus*, the stinging nettle (*uro*, I burn).

trees, of which *Platanus orientalis* and *occidentalis* are familiar species.

(33.) *Urticaceæ* (*the Nettle Order*).—Flowers monœcious or dicœcious, in panicles or tufts. Perianth simple, tetramerous (2 + 2, Fig. 215); in the ♀ flowers the two inner parts are considerably larger than in the ♂. Stamens four, opposite the parts of the perianth. Ovary superior, one-celled, one-seeded, with one (tapered) or two stigmas. Fruit an indehiscent nut or a berry.—[1700.]

FIG. 215. Stinging nettle (*Urtica dioica*).

In the temperate regions the nettles are herbs or shrub-like plants, frequently with stinging hairs, always without milky juice. The representatives of the class in warmer regions are frequently trees containing milky juice. There are four families :—

1. *Urticeæ* (*the Nettles*).—Fruits single nutlets ; one stigma ; without milky juice ; succulent herbs ; chief genera the *stinging nettles* (*Urtica urens* and *dioïca*) and pellitory (*Parietaria*).

2. *Moreæ* (*the Mulberries*).—Fruits aggregate, indehiscent ; mostly two stigmas ; nearly all shrubs or trees with milky juice. To the Moreæ belongs the mulberry trees (*Morus alba* and *nigra*), cultivated as affording food for silkworms. The mulberry originally comes from China.

3. *Cannabineæ* (*the Hemps*).—Fruits single, indehiscent ; stigmas two ; no milky juice ; herbs and low shrubs. Hemp (*Cannabis sativa*) and hops (*Humulus Lupulus*) are important species belonging to this family ; their uses are well known.

4. *Artocarpeæ* (*the Bread-Fruits*).—Fruit a single-seeded berry, or a peculiar aggregate fruit ; trees and shrubs with alternate leaves and milky juice. The Artocarpeæ include the great fig genus (*Ficus*) ; several species important, *e.g.*, *Ficus Carica* (the fig-tree), introduced from the east into Greece, Italy, and Spain, where it is largely cultivated, and yields the common fig (in the pulp of which the true *fruits* are imbedded) ; also the india-rubber tree (*Ficus elastica*), a native of the East Indies, whose milky juice is a source of the india-rubber of commerce. The fruits of bread-fruit trees (*Artocarpus incisa*, &c., cultivated in the Tropics) are highly prized as articles of food.

III.

CENTROSPERMÆ.[1]

The *Centrospermæ* are choripetalous dicotyledons with double floral envelopes, forming a calyx and corolla, or with only

[1] Greek, *centron*, the centre ; *sperma*, a seed.

one floral envelope developed. (In the latter case they may be distinguished from plants of both the foregoing classes by their never being trees or shrubs, by never bearing catkins, and by their flowers being almost always hermaphrodite.) Each flower contains *one* ovary, which is always one-celled, never several-celled, though occasionally divided by false dissepiments (comp. Fig. 98, II.); it is one or many-seeded. The ovule or ovules are always central, never parietal. *They are attached to a free central placenta*, a mode of attachment found in none of the other Choripetalæ.

The Centrospermæ are herbs or shrub-like plants, with simple leaves and flowers, which are frequently arranged in heads or tufts. They form two orders, the first of which has flowers with a perianth, the second double floral envelopes.

(34.) *Oleraceæ* (*the Spinach Order*).—Flowers with perianth, di-, tri-, or tetramerous, rarely absent. Stamens arranged in one or two whorls, of which the members are frequently not all developed, so that no general statement can be made as to their number; *e.g.*, there may be one, two, three, four, five, six, seven, eight, or numerous stamens in a flower. Ovary free, one-celled, and almost always one-seeded; the large ovule attached to the middle of the floor of the ovary by a long, often curved stalk (Fig. 216); styles several. Fruit a hard, indehiscent nutlet.—[1200.]

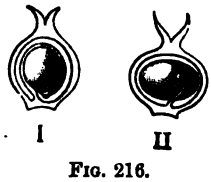


Fig. 216.

Longitudinal section through the ovary of (I.) *Chenopodium*, (II.) *Blitum bonus Henricus*. After Eichler.

Herbs or shrub-like plants with opposite (decussate), alternate, or whorled leaves, and very inconspicuous greenish flowers. They are found chiefly in dry places in the Temperate Zones. To many salt is necessary for their proper development, and hence many species grow exclusively by the sea shore or by salt springs. Two families.

Polygoneæ (*the Sorrel Family*).—Leaves provided with membranous stipules, either free or united in the form of a sheath around the stem. Perianth with from three to eight parts; stamens three to nine, or numerous; ovary always one-seeded, with several styles or stigmas; fruit nut-like (Fig. 217). Shrubs or herbs with simple leaves, found in all climates. Native genera are *Rumex* (dock) and *Polygonum*, which includes the buck-wheat (*P. Fagopyrum*) and many species. Rhubarb (*Rheum rhaponticum*, *&c.*) is also one of the Polygoneæ.

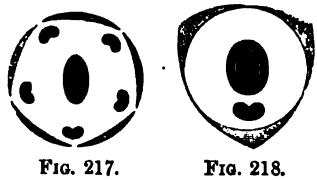


Fig. 217. Fig. 218.

Fig. 217.—*Polygonum amphibium*. Fig. 218.—*Blitum virgatum*.

2. *Chenopodiæ* (*the Goosefoots*). — No stipules. Perianth membranous, green, rarely brightly coloured, in the ♂ flowers three to five lobed, in the ♀ flowers mostly two-lobed. Stamens free, inserted on the bases of the perianth lobes; as many or fewer, never more numerous than these. Ovary one-celled, one-seeded, with two or four lobed stigma. Fruit dry, indehiscent (Fig. 218). Habitat, temperate regions, the sea shore, and salt steppes (Central Asia and Siberia). Home genera—*Atriplex* (orach), *Chenopodium* (goosefoot), &c. Cultivated species *Spinacia oleracea* (spinach) and *Beta vulgaris* (beet-root). Soda used to be obtained from the ashes of several other species found in salt marshes (*e.g.*, *Salsola Kali*).

(35.) *Caryophylleæ* (*the Pinks*).—Ovary one-celled, composed of from two to five carpels; at first many-celled, placentation axile, afterwards (by absorption of septa) central, with many ovules. Fruit a capsule, opening by teeth. Stamens usually five or ten; hypogynous, like the floral envelopes inserted on the receptacle (Fig. 59). Floral envelopes double, consisting mostly of a green calyx and a brightly coloured corolla; both pentamerous (Fig. 219).—[1000.]

Fig. 219. *Silene inflata.*

Herbs of the temperate regions, well represented in our own flora. Three families.

1. *Sileneæ* (*Pinks*).—Sepals united into a five-toothed calyx; petals five; stamens ten, inserted on a thickened receptacle under the ovary; fruit many-seeded; styles two to five. Leaves opposite, without stipules. Home genera—*Dianthus* (including garden pinks, carnations, &c.), *Saponaria* (soap-root), *Silene* (catchfly), *Lychnis* (campion), *Agrostemma* (corn-cockle), &c.

2. *Alsineæ*.—Calyx tetr- or pentamerous, sepals distinct or deeply cleft; stamens ten or fewer, forming a circle; petals five; fruit many-seeded; styles two and five. Leaves opposite, without stipules. Home genera—*Sagina*, *Spergula*, *Arenaria* (sand-wort), *Stellaria* (stoch-wort), *Cerastium*, &c.

3. *Paronychieæ*.—Calyx tetr- or pentamerous; petals small or absent; stamens three or five, united to the calyx; fruit mostly one-seeded; leaves opposite, with scarious stipules. Small weeds with inconspicuous flowers. *Herniaria*, *Illecebrum*, and *Seleranthus* are typical genera.

IV.

MONOCHLAMYDEÆ.[1]

The *Monochlamydeæ* are choripetalous dicotyledons, with unisexual or hermaphrodite flowers, having mostly a brightly

[1] Greek, *monos*, one; *chlamys*, a mantle.

coloured perianth. The petals of the perianth are united into a longer or shorter tube, with three to five lobed or irregular throat. Ovary superior or inferior, three to many seeded, never with central placenta; fruit usually dehiscent. Flowers never in catkins. Three orders.

(36.) *Euphorbiaceæ* (*Euphorbias*).—Flowers monœcious. Perianth hypogynous, four to five lobed, the lobes alternating with a fleshy involucre, enclosing five ♂ and one ♀ flower; the whole forms what is termed a *Cyathium*. Stamens free, often numerous; ovary mostly stalked, three-celled, each cell one-seeded; fruit when ripe dividing into three at the common central column (Fig. 220).—[3500.]

FIG. 220. *Euphorbia Cyparissias.*

The *Euphorbiaceæ* are herbs, shrubs, or trees, with cylindrical or angular stems, containing milky juice. The leaves are scattered (in some cases are abortive), simple, and entire, rarely palmate. The *Euphorbiaceæ* are most numerous and attain their greatest development in the Tropics; in this country they are chiefly represented by the genus *Euphorbia*, which contains many species. *Ricinus communis* is much cultivated for the sake of the castor-oil yielded by its seeds. (*Phyllanthus* (Fig. 20) also belongs to this order.)

(37.) *Thymelæaceæ* (*the Lace-Bark Order*).—Flowers regular, ☿; Perianth hypogynous, four to five lobed, tubular; stamens four or eight, adnate to the tube of the corolla; ovary sessile, one-celled, one-seeded, with one style and one stigma; fruit a berry (Fig. 221).—[300.]

FIG. 221. *Daphne Mezereum.*

The Thymelæaceæ are low shrubs with simple leaves. They belong to the warmer regions of both Temperate Zones, and are especially numerous in South Africa. They grow in dry places. *Daphne Mezereum*, with red poisonous berries, is a typical home species.

(38.) *Aristolochiaceæ* (*Aristolochias*).—Flowers ☿; perianth epigynous, almost regularly three lobed, or forming a long tube with irregular throat. Stamens (with or without filaments) united to the ovary, six or twelve. Ovary six-celled, each cell with two rows of ovules. Stigmas six, or one, six-parted (Fig. 222).—[200.]

FIG. 222. *Asarum europæum.*

The Aristolochiaceæ are land plants of the Torrid and Temperate Zones; they have a persistent, sometimes climbing stem, and alternate simple leaves. *Aristolochia Clematitis* and *Asarum europæum* are representative native species. A noteworthy allied order are the *Rafflesiaceæ*, of which *Rafflesia Arnoldi*, an entirely leafless gigantic parasitic plant of Java and Sumatra, is a remarkable species. Its flowers are the largest known, measuring about a yard across. When faded they turn of a brownish colour, and smell like carrion, deceiving even the flies, which come and lay their eggs on them. Mistletoe (*Viscum album*), the well-known parasite, is also allied.

V.

UMBELLIFLORÆ.[1]

The *Umbelliflorœ* are choripetalous dicotyledons with hermaphrodite flowers, double floral envelope, and a perfectly inferior ovary. Calyx usually very slightly developed, in which case it forms a cushion-like ring, crowning the ovary immediately below the insertion of the petals. Corolla tetr- or pentamerous, its members alternating with those of the calyx, frequently not all of similar shape. Only *one* pent- or tetramerous whorl of stamens is developed, its members inserted at the throat of the calyx, and opposite the sepals. Ovary large, elongated, two-celled, each cell one-seeded (very rarely five-celled and five-seeded). Styles one or two, inserted on the flattened disk crowning the ovary. Inflorescence a simple or compound umbel or umbellate cyme. Two orders:—

(39.) *Umbelliferœ.*—Calyx very slightly developed, ring-like or five-toothed. Petals five, inflexed tip; frequently of different shapes, the flower being thereby rendered symmetrical (Fig. 233, I.). Calyx and corolla alike arise from the disk on the top of the ovary (II.). Stamens five, alternating with the petals (occasionally fewer by suppression). Sepals and petals rolled inwards in the bud. Ovary composed of two carpels (II. *f*, III.-VI.), united throughout their entire length, each having a short, simple style (*g* II.). The upper surface of the carpels forms a two-fid fleshy disc in the centre of the flower (*d* I., II.) The ovary (*f* II.) is two-celled, each cell containing one large ovule, pendulous by a long stalk. When the fruit is ripe the two carpels separate and form two merocarps[2] (IV.), which remain attached above to a forked

[1] Latin, *umbella*, dim. of *umbra*, a shade; *floreo*, to flourish.
[2] Greek, *meris*, a part; *carpos*, a fruit.

carpophore (comp. Fig. 126). The external surface of the pericarp is variously channelled and ridged (V., VI.). The inflorescence is sometimes a *simple* (see Fig. 105, *e.g.*, water penny-wort, *Hydrocotyle*), more usually a *compound* umbel (comp. Fig. 107, III. *a*, and Fig. 117, *a*), provided with bracts and bractlets, rarely a capitulum (*Eryngium, Dondia*).—[1300.]

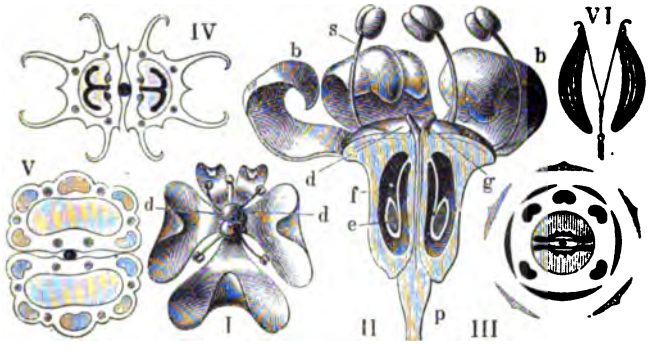


FIG. 223.

Umbelliferæ.—I. Floret of *Heracleum Sphondylium;* six times enlarged. II. The same of *Pastinaca sativa*, longitudinal section; fifteen times enlarged. III. Diagram of Umbelliferæ (*Heracleum Sphondylium*). IV. Fruit of carraway (*Carum Carui*); enlarged six times. V. Cross section of fruit of *Cicuta virosa* (water hemlock). VI. The same of *Caucalis daucoides*. *b* Petals, *s* Stamens, *f* Ovary, *c* Ovules, *g* Styles, *d* Disk, *p* Flower-stalk.

The Umbelliferæ are annual or perennial herbs, rarely shrubs. The stem is frequently hollow, its external surface channelled. It is angular and jointed, a leaf arising at each joint. The leaves are rarely simple (*Bupleurum*, comp. Fig. 40), but as rarely really compound. They are almost always pinnately cleft, and that so deeply that the indentations *almost* reach the midrib. They are either pinnate, bi-pinnate, tripinnate, or compoundly pinnate. The roots of many Umbelliferæ are fleshy and esculent—*Daucus Carota* (carrot), *Pastinaca sativa* (parsnip), *Apium graveolens* (celery). The fruits of others are used as spice, or yield aromatic oils—*e.g.*, carraway (*Carum Carui*), fennel (*Fœniculum officinale*), dill (*Anethum graveolens*), anise (*Pimpinella Anisum*), coriander (*Coriandrum sativum*). In some cases the whole plant is used in food—*e.g.*, parsley (*Petroselinum sativum*). Several native species of Umbelliferæ are poisonous—*e.g.*, water hemlock (*Cicuta virosa*, Fig. 117), the hemlock (*Conium maculatum*), and fool's parsley (*Æthusa Cynapium*). The Umbelliferæ form a very distinct natural order, the various genera of which are easily recognised by their peculiar and similar habit. They are found plentifully in the Temperate Zones of both hemispheres, not at all in the Arctic

regions, and very sparingly in the Tropics—in fact, only on mountains where the climatic conditions resemble our own. They are indigenous to Central and South Europe, the East, and Central Asia. Other species worthy of note are *Sanicula europæa*, *Eryngium* (sea-holly), *Ægopodium Podagraria*, *Pimpinella Saxifraga* (pimpernel), *Sium*, *Libanotis*, *Angelica sylvestris*, *Archangelica officinalis* (angelica), *Peuredanum*, *Heracleum Sphondylium*, *Laserpitium*, *Torilis*, *Anthriscus*, *Chærophyllum*, &c.

(40.) *Cornaceæ* (*the Dogwood Order*).—Calyx a slightly-toothed ring: stamens four, opposite the sepals; style one; ovary two-celled and two-seeded; fruit drupaceous (Fig. 224 and Fig. 62).—[80.]

Fig. 224. Dogwood (*Cornus sanguinea*).

A small order of the north temperate regions. Native species *Cornus sanguinea* (dogwood), and *C. mascula* (the Cornelian cherry). Related are the *Araliaceæ* or ivy order, with similar but pentamerous flowers, and two or five-celled ovary. *Hedera Helix* (ivy), and *Aralia Sieboldii*, a favourite greenhouse plant.

VI.

Saxifraginæ.[1]

The *Saxifraginæ*, or Saxifrages, are choripetalous dicotyledons whose flowers, in contradistinction to those of the Umbellifloræ, have a well developed calyx, which, like the corolla, is pent- or tetramerous. Petals sometimes not well developed. Stamens five or numerous, arranged in one or two whorls, sometimes reduplicated; when there is only one whorl present, it is usually opposite the sepals. Ovary rarely four-celled, usually two-celled, many-seeded. Corolla and stamens (as in the Umbelliferæ) either epigynous or perigynous. Flowers regular or symmetrical. Important orders, three.

Fig. 225. Saxifrage (*Saxifraga granulata*).

(41.) *Saxifragaceæ* (*the Saxifrage Order*).—Calyx tetr- or pentamerous, free, or adhering to the ovary; petals four or five (rarely suppressed); stamens in one whorl (four or five), or in two whorls (eight or ten); ovary composed of two carpels, one or two celled, many-seeded. Fruit a capsule (Fig. 225).—[800.]

Small herbs of the Temperate and especially of the colder Zones,

[1] Latin, *saxum*, a rock; *frango*, I break.

Alpine and sub-Alpine plants (Switzerland). Several native species—saxifrage (*Saxifraga*, pentamerous flowers, two-celled ovary), and *Chrysosplenium*, tetramerous flowers, one-celled ovary. *Parnassia palustris* is related.

Fig. 226.
Currant (*Ribes rubrum*).

(42.) *Ribesiaceæ* (*the Currant Order*).—Calyx four or five lobed, slightly adhering to the ovary; petals four or five, inserted on the throat of the calyx; stamens four or five, opposite the sepals, arranged in one whorl; ovary one-celled, many-seeded, with parietal placentæ. Fruit a berry (Fig. 126).—[60.]

Shrubs, mostly thorny, with alternate leaves and esculent fruit, common in temperate regions. The gooseberry (*Ribes Grossularia*) and the currant (*R. rubrum*), &c., are our best-known species.

(43.) *Philadelphaceæ* (*the Mock Orange Blossom Order*).—Calyx tetramerous; petals four; stamens in two whorls of four, or more numerous, rarely ten; ovary three or four celled, each cell many-seeded. Fruit a capsule (Fig. 227).—[50.]

Fig. 227.
Mock orange blossom (*Philadelphus Coronarius*).

Thornless shrubs, with simple, opposite leaves, natives of the Temperate Zones. The mock orange blossom (*Philadelphus Coronarius*—comp. Fig. 63, I. II.), introduced into this country from South America, is now largely cultivated, as are also various species of *Deutzia* (comp. Fig. 142, *a*).

VII.

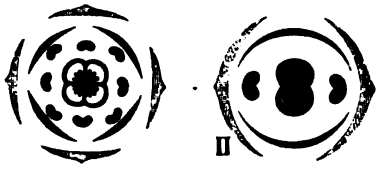
MYRTIFLORÆ.

The *Myrtiflorœ* (Myrtles) are choripetalous dicotyledons, our native species having well-developed sepals and petals. Calyx di-, tetra-, or pentamerous; corolla tetra- or pentamerous. Stamens either as many (two or four) as the sepals, and arranged in one whorl, or twice as many (eight or ten) in two whorls. Ovary two or four celled, few or many seeded, inferior or superior.

Note.—The Myrtifloræ and the Saxifraginæ are very much alike. Our native myrtles may be distinguished from our saxifrages in two ways:—(*a.*) Their ovary is completely inferior, that of the saxifrages median; (*b.*) In the myrtles we find eight stamens and a four-celled

ovary, or two stamens and a two-celled, two-seeded ovary, features never found in the saxifrages. Of the Myrtifloræ there are numerous orders; the following are indigenous:—

(44.) *Onagraceæ* (*the Evening Primrose Order*).—Ovary completely inferior; sepals two or four; petals two or four; stamens two to eight; ovary either two-celled, with each cell one-seeded, or four-celled and each cell many-seeded; style one, stigma four-cleft; seeds mostly elongated. Fruit a siliqua or capsule (Fig. 228).—[300.]



I. II.

Fig. 228.

I. Willow herb (*Epilobium angustifolium*). II. Nightshade (*Circæa lutetiana*).

The Onagraceæ are found everywhere, but mostly in the warmer regions of North and South America. Native genera are *Epilobium* (willow herb, of which there are many species—Fig. 61); *Œnothera* (the Evening Primrose, introduced from Virginia in the seventeenth century); *Circæa* (enchanter's nightshades), and *Trapa* (*Trapa natans* is the water chestnut). Many species of the genus *Fuchsia* are well-known cultivated plants.

(45.) *Lythraceæ* (*the Loosestrife Order*).—Ovary superior; calyx toothed, persistent, tubular; petals and sepals equal in number; petals alternate with the sepals, and adherent to the calyx, as are also the stamens. Ovary two-celled, many-seeded; style one. Fruit a capsule (Fig. 229).—[300.]

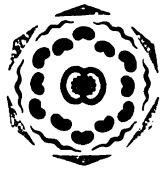


Fig. 229.

Loosestrife (*Lythrum Salicaria*).

The Lythraceæ abound in warmer and subtropical regions; in this country they are but sparingly distributed. Our most important species, *Lythrum Salicaria*, has six sepals, six petals, and twelve stamens.

VIII.

Rosifloræ.

The *Rosiflorœ* are choripetalous dicotyledons with well developed double floral envelope, corolla and calyx always regular, and either superior (as in the apples) or inferior (as in the almonds and roses). Calyx penta-, rarely tetramerous, forming below a more or less elongated tube called the *Receptacle*.[1]

[1] Many botanists regard this as belonging to the axis.—Tr.

The five petals and the stamens arise from the throat of the receptacle (Calycifloræ, comp. Fig. 90, II., and Fig. 92, *a*). The number of stamens is indefinite, rarely few (as many as the petals), usually numerous (12 to 100). The ovary is very varied in its form. Either it is single, and one or several celled, or it is apocarpous, and we get several or many simple ovaries in a single flower. Each one-celled ovary has a style (Fig. 230); if the ovary is apocarpous, then there are as many styles as cells or carpels. The style is either at the apex of the ovary (Fig. 230, I., IV., V., IX.), or it arises from the side (II., III.); stigma small, not prominent (V.-IX.), knob-like (I.-III.), or feathered (IV.). Each ovary either single-seeded (I.-IV.) or several-seeded (VI., VII.).

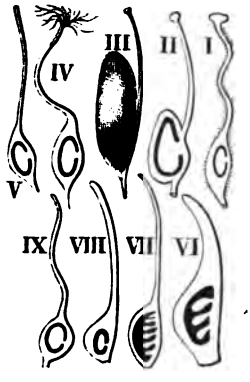


FIG. 230.

Ovaries of Rosiflorœ.—I. Rose (*Rosa pimpinellifolia*); II. Ladies' mantle (*Alchemilla vulgaris*); III. Lesser ladies' mantle (*A. arvensis*); IV. Salad-burnet (*Poterium sanguisorba*); V. Bramble (*Rubus fruticosus*); VI. *Spiræa lanceolata*; VII. Quince (*Cydonia vulgaris*); VIII. Pear (*Pyrus communis*); IX. Cherry (*Prunus Cerasus*).

Three orders of Rosifloræ are indigenous to this country:—

(46.) *Pomaceæ (the Apple Order).*—Corolla superior. Calyx five-toothed, campanulate or cup-shaped below, more or less adherent to the ovary, persistent. Petals five; stamens about twenty; both inserted on the throat of the calyx; ovary one, inferior, two to five celled, each cell at least two-seeded; styles two or five. Fruit a pome, surrounded by the withered calyx (Fig. 231).—[160.]

Trees or shrubs with scattered, stalked, mostly simple, leaves, and small stipules. They are natives of the Temperate regions, bear esculent fruits, and have accordingly been cultivated from the most ancient times. Home species are the medlar (*Mespilus germanica*), the Hawthorn (*Cratægus Oxyacantha*), the quince (*Cydonia vulgaris*), the apple-tree (*Pyrus Malus*), the pear-tree (*P. communis*), the mountain ash (*P. aucuparia*), &c.

FIG. 231.

Pear (*Pyrus communis*).

(47.) *Amygdalaceæ (the Almond Order).*—Corolla inferior; calyx free, pentamerous, deciduous; petals five; stamens twenty, free, like the corolla inserted on a disk within the calyx. Ovary one,

one-celled and two-seeded, with one style. Fruit a drupe, containing only one seed (the other abortive, though in the almond two seeds are frequently found in one fruit) (Fig. 232).—[100.]

FIG. 232. (*Prunus Padus*).

The Amygdalaceæ are trees or shrubs with scattered, simple, dentate leaves and small stipules (comp. Fig. 53). They are nearly all indigenous to the North Temperate regions; the fruit (a drupe) and seeds of many are highly prized as articles of food. The young shoots, the leaves, and the seeds yield prussic acid. The most important species are the almond (*Amygdalis communis*), the peach (*A. Persica*), the apricot (*Prunus Armeniaca*), the sloe (*P. spinosa*), the greengage (*P. insititia*), the damson (*P. domestica*), the plum (*P. cerasifera*), the Cherry (*P. avium*), the dwarf-cherry (*P. Cerasus*).

(48.) *Rosaceæ* (*the Rose Order*).—Corolla inferior; calyx four or five lobed, forming below a tube or cup which contains the ovaries;[1] the five (seldom four) petals are, like the numerous stamens (12-100), inserted on the throat of the calyx. Ovaries several, each one-celled and one-seeded, or several-seeded. Fruit mostly a nutlet; more rarely drupaceous (Fig. 233).—[1070.]

FIG. 233. Dog-rose (*Rosa canina*.)

Trees, shrubs, or herbs of the Temperate regions of both hemispheres; leaves compound, stem and leaf-stalks often beset with thorns or prickles. Three families.

1. *Spireæ*.—Fruits mostly five, each two to four seeded, dehiscent. Shrubs and shrub-like plants, with pinnate or compound leaves, and flowers in large clustered panicles; indigenous to the North Temperate regions. The Spireæ include the genus *Spiræa*, to which belong several home species; many have been introduced into our gardens from Asia.

2. *Potentilleæ*.—Fruits many, one-seeded, nut-like or drupaceous, indehiscent; calyx persistent. Shrubs and herbs of the Temperate and Arctic regions of both hemispheres; some also Alpine. Important home genera—*Geum*, *Rubus* (bramble and raspberry), *Fragaria* (strawberry), *Potentilla*; these are nearly all represented by numerous species.

3. *Roseæ*.—Fruits many, one-seeded, nut-like; calyx, when ripe, fleshy and coloured, forming a thick covering (hip) for the fruits. Indigenous to the warmer regions of the North Temperate Zone. The genus *Rosa* includes many species which grow wild in this country. The cultivation of *Rosa centifolia* (the garden rose) is as old as history itself. Otto or attar of roses is the essential oil obtained from the petals of *R. centifolia* and *R. damascena*. Related to the Rosaceæ are the *Chrysobalaneæ*, trees with simple, stalked, mostly leathery leaves, found only in the Tropics. The fruits of some species are esculent.

[1] See Note, p. 146.—Tr.

IX.

LEGUMINOSÆ.[1]

The *Leguminosæ* are choripetalous dicotyledons with superior ovary and two floral envelopes. Calyx (Fig. 234, *d*) free; petals united, five-toothed or five-lobed, bilabiate, or with lobes of similar shape and size. Corolla springing from the bottom of the calyx, irregular, originally composed of five petals; by union of the two lower petals apparently reduced to four. (In a few exceptional cases all the petals are united at their bases.) The upper petal is stalked and bent back (*a*), it is called the *vexillum* or *standard*; the two side petals are the *alæ* or *wings* (*b*, *b*), the two lower (united) form the *carina* or *keel*. Within these are the stamens and the ovary. The comparative size of the different parts of the corolla is subject to great variations in the different genera. In Fig. 235 we have a full-sized representation of the beautiful coral-red flower of *Erythrina Crista galli*, an almost tree-like, papilionaceous plant. The vexillum (*a*) and the carina (*c*) are large and conspicuous; the wings seem almost entirely absent; all that remains of them are the small red petals (*b*), one on each side of the vexillum.

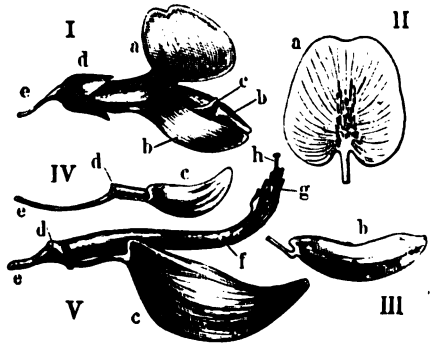


FIG. 234.

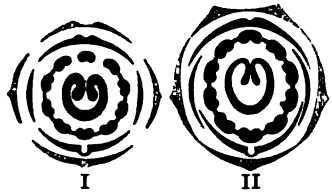
Laburnum (*Cytisus Laburnum*).—I. Entire flower; II. Standard; III. Wings; IV. V. Keel; *d* Calyx; *e* Flower-stalk; *f* Filaments; *g* Anthers; *h* Style and Stigma.

FIG. 235.

Flower of *Erythrina Crista galli*; nat. size. (The description of the parts in Fig. 234 applies also to Fig. 235.)

[1] Latin, *legumen*, a pod.

The stamens, ten in number, spring like the corolla from the bottom of the calyx. Either they all unite to form one bundle (Fig. 234, V.), or nine are united, the tenth free (comp. Fig. 96, IV.), (Fig. 236, I. II.). The ovary is peculiar, and is characteristic only of the Leguminosæ. It is composed of one carpel, which lies opposite the lowest sepal. It is one-celled and several-seeded, the ovules (several or many) lying in two long rows opposite to the vexillum. Style one. Fruit a legume, dehiscent by both sutures, or lomentum (comp. Fig. 127). Only one sub-order of Leguminosæ is indigenous to this country.



I II

FIG. 236.

I. Vetch (*Vicia Cracca*). Stamens in two bundles (9 + 1). II. Laburnum (*Cytisus Laburnum*). Stamens all in one bundle.

(49.) *Papilionaceæ.*—The characteristics of the Papilionaceæ have been given above.—[3000.]

The Papilionaceæ form one of the largest and most well-defined natural orders, the peculiar structure of their flowers and fruit rendering them easily distinguishable. Many species are cultivated as garden plants for the sake of their handsome flowers; many for the sake of their seeds, which form food both for man and the domestic animals. The order is represented in all climates; in the Tropics the prevailing species are mostly trees and shrubs; in sub-tropical regions, shrub-like plants; and in the Temperate and colder Zones, mere herbs. Hence, from the character of the Papilionaceæ in any region, we may form an idea of the general characteristics of its entire flora.

Our home Papilionaceæ may be divided into several families and a number of sub-families, which are distinguished from one another by the formation of the legume, by the manner in which the filaments are united by the form of inflorescence, &c. As, however, these features are not constant in all members of each group, it will be sufficient here simply to indicate some of the more important European genera. These are—*Ulex* (whin), *Sarothamnus* (broom), *Genista*, *Cytisus* (laburnum), *Lupinus* (lupin), *Ononis*, *Anthyllis*, *Medicago* (snail clover), *Melilotus*, *Trifolium* (clover, many species), *Lotus*, *Robinia* (locust, introduced from North America), *Astragalus*, *Ornithopus*, *Onobrychis*, *Vicia* (vetch), *Ervum* (lentil), *Pisum* (pea), *Lathyrus* (everlasting pea), *Phaseolus* (bean). Many foreign species are noted for their useful products, *e.g.*, *Tragacanth* (*Astragalus verus*, *A. creticus*, *A. Tragacantha*, from which gum is obtained), *Glycirrhiza* (liquorice), *Cicer* (chick pea), *Indigofera tinctoria* (indigo), &c.

Related to the Papilionaceæ are the *Mimoseæ* or acacias. These

are tropical trees, more rarely shrubs, with bi-pinnate or compound pinnate leaves. *Acacia nilotica* abounds in the valley of the Nile and the oases of the Libyan desert; *A. Sajal* is characteristic of the Tintumma steppe in the southern part of the Sahara; from *A. Vereck*, a native of Tropical Africa, gum arabic is obtained; from *A. Catechu*, in the East Indies, gum catechu.

A third related order are the *Cæsalpiniæ*, mostly trees, growing only in warm climates. Senna leaves are obtained from a species of *Cassia;* the pod of *Ceratonia Siliqua* is the well-known locust or carob bean; logwood is the wood of *Hæmatoxylon campechianum*, a West Indian species, Brazil wood of *Cæsalpinia echinata*, a Brazilian species.

X.

POLYCARPICÆ.[1]

The *Polycarpicæ* are choripetalous dicotyledons with superior pistil. Stamens and floral envelopes are inserted on the receptacle (Thalamifloræ). They are distinguished, on the one hand, by their numerous separate one-celled ovaries, each composed of one carpel, on the other, by their usually indefinite hypogynous stamens. The *Berberideæ*, however, have, like the preceding order, a single ovary composed of one carpel, and a definite number of stamens, while the *Nymphæaceæ* orders furnish a transition to the next order (p. 155), chiefly on account of the peculiar formation of the ovary, as we shall presently see.

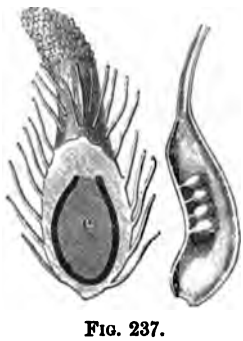


FIG. 237.
Single and several-seeded ovaries of *Ranunculaceæ*.

Usually both floral envelopes are present, more rarely (*Ranunculaceæ*) we find a perianth of six or more parts; calyx penta-, rarely hexamerous; petals five, six, or numerous, never four (as in the following class). Stamens six or numerous (by radial reduplication). The separate ovaries are composed of one carpel, are one-celled and mostly one-seeded, more rarely several-seeded (Fig. 237). Three orders represented in this country.

(50.) *Berberideæ* (*the Barberry Order*).—Sepals four or six, often petaloid; petals also four or six, opposite to sepals, each

[1] Greek, *polys*, many; *carpos*, a fruit.

with an appendage on the inner side of its base. Stamens as many as and opposite to the petals. Ovary one, simple, one-celled, few-seeded; style one. Fruit a berry (Fig. 238).—[100.]

Fig. 238. Berberry (*Berberis vulgaris*).

A small order of the Northern Temperate regions (Europe, Siberia, China, Japan, North America). Shrubs, often thorny, rarely shrub-like herbs, with stalked, alternate leaves. Native species Barberry (*Berberis vulgaris;* flowers hexamerous); *Epimedium* (an Alpine species, flowers tetramerous) has been introduced; also the Mahonia (*Mahonia Aquifolium*, a North American species; flowers hexamerous).

Related to the Berberideæ are the *Menispermaceæ*, *Myristicaceæ*, *Anonaceæ*, and *Magnoliaceæ*, mostly trees of tropical and sub-tropical

Fig. 239. Traveller's Joy (*Clematis Vitalba*).

Fig. 240. Anemone (*Anemone nemorosa*).

Fig. 241. Buttercup (*Ranunculus acris*).

Fig. 242. Monk's-hood (*Aconitum Napellus*).

regions. "Cocculus Indicus" consists of the poisonous berries of *Anamirta Cocculus*, an East Indian species of Menispermaceæ; the nutmeg is the seed of *Myristica fragrans*, a species of Myristicaceæ found in the Moluccas; the tulip-tree (*Liriodendron tulipifera*) and the magnolia (*Magnolia sp.*) are trees of the order Magnoliaceæ, much cultivated for their handsome flowers.

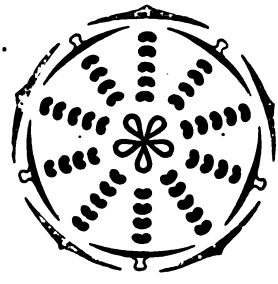


Fig. 243. *Aquilegia vulgaris.*

(51.) *Ranunculaceæ* (*the Crowfoot Order*).—Sepals usually five, more rarely three, four, or six; petals equal to and alternating with the sepals, or more numerous (*e.g.*, three or four times as many), simple, or developed into peculiar sac-like structures. In many cases the flower consists of a perianth of four, five, six, or more parts (Figs. 239, 240). Flower either regular or symmetrical (Fig. 242). Stamens indefinite, variously

arranged (Figs. 239-243). Ovaries usually several or many, very rarely one. Each ovary simple, composed of one carpel, one or few seeded. Fruits aggregate, often forming a rounded mass, the individual fruitlets either indehiscent achenes, or, if several-seeded, dehiscent by one suture.—[1200.]

The Ranunculaceæ are herbs, more rarely shrubs, with alternate or opposite stalked leaves, usually much cleft (Fig. 34). They are to be met with all over the world, but chiefly in the temperate and colder regions. Many species are poisonous.

Families of Ranunculaceæ.

I. Leaves opposite, flowers simple, a four-parted perianth; shrubs, ... 1. CLEMATIDEÆ.

II. Leaves alternate; flower a simple perianth, or with calyx and corolla; petals and sepals five or more; herbs.

A. Fruitlets one-seeded, indehiscent.

a. Ovule pendulous. Flower a perianth, or with calyx and corolla; in the latter case the petals flat, with no scales at the base, 2. ANEMONEÆ.

b. Ovule erect. Flower with calyx and corolla; petals mostly with scales at the base, . 3. RANUNCULEÆ

B. Fruitlets several-seeded, mostly dehiscent.

a. Anthers opening outwards. Flowers sometimes symmetrical, the envelopes often forming a perianth, ... 4. HELLEBOREÆ.

b. Anthers opening inwards. Flowers always regular, the envelopes never forming a perianth, ... 5. PÆONIEÆ.

Important types of these families are—1. *Clematideæ.*—Traveller's joy (*Clematis vitalba*) and other cultivated species of Clematis; climbing shrubs, mostly with large violet flowers, and tetramerous perianth. 2. *Anemoneæ.*—Meadow rue (*Thalictrum*), hepatica (*Hepatica triloba*), pasque-flower (*Pulsatilla pratensis*), wood anemone (*Anemone nemorosa* with white, *A. ranunculoïdes* with yellow flowers), Adonis (*Adonis æstivalis* and *vernalis*). 3. *Ranunculeæ* (the crowfoots).—Water buttercup (*Batrachium*, with white flowers and submerged leaves, finely divided, Fig. 36), buttercup (*Ranunculus*, many home species, mostly with deeply cleft leaves). 4. *Helleboreæ* (the hellebores).—Marsh marigold (*Caltha palustris*), hellebore (*Helleborus*), *Nigella*, *Aquilegia* (columbine), *Delphinium* (larkspur), *Aconitum* (monk's-hood), nearly all cultivated species. 5. *Pæonieæ* (the peonies).—Herb Christopher (*Actæa*, with small white flowers), peony (*Pæonia*, with large bright or deep red flowers, a favourite garden plant).

(52.) *Nymphæaceæ* (*Water-Lilies*).—Sepals mostly five, quincuncial (Fig. 244, I.), green or petaloid, corolla regular,

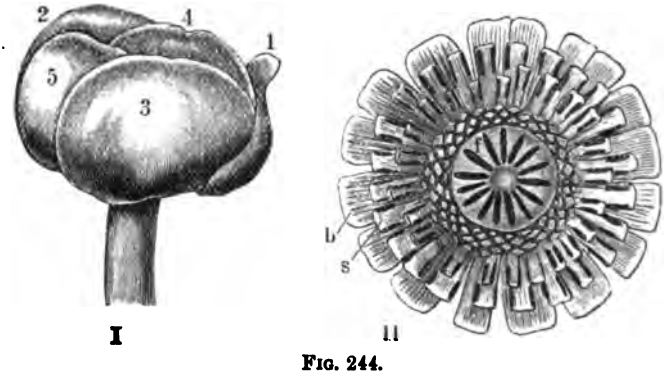


FIG. 244.

Water-lily (*Nuphar luteum*).—I. Flower. II. Petals. *b* Stamens (*s*) and ovary (*f*) viewed from above; nat. size.

petals numerous (*b*, Fig. 244, II.); stamens many, partly petaloid, forming several (*e.g.*, five) whorls. Ovary many-celled (Fig. 245, I.–III.), resting on a flat disk (*f*, Fig. 244, II.). Fruit capsular.—[35.]

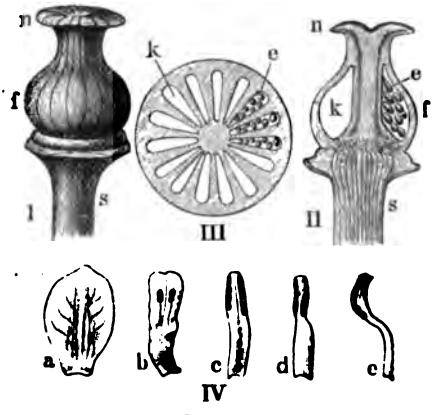


FIG. 245.

Water-lily (*Nuphar luteum*).—I. Ovary. II. The same, in longitudinal section. III. Same, transverse section. IV. *a–e* Transition forms between petals and stamens, nat. size. III. one and a half times enlarged. *s* Flower stalk; *f* Ovary; *k* Cells of ovary; *e* Ovules; *n* Stigma.

The Nymphæaceæ, a small order characteristic of warm and temperate regions, are in many respects remarkable. As regards their petals, for instance, we find in a single flower all the stages of transition between a perfect petal and a perfect stamen (Fig. 245, IV. *a–e*); they therefore afford the strongest evidence for the theory of the development of stamens from leaf organs. Further, the Nymphæaceæ link together the Polycarpicæ and the Rhœadinæ. The carpels, in two foreign lotus-like families of Nymphæaceæ (*Cabombeæ* and *Nelumboneæ*), are separate, forming in a single flower several one-celled, many-seeded ovaries, while the flowers of our own water-

lilies have but *one* many-celled ovary, composed of many carpels, each cell containing numerous seeds. In structure, as in external appearance, this ovary considerably resembles that of the Rhœadinæ.

The Nymphæaceæ are herbaceous water-plants, with long-stalked, circular, reniform, or ovate floating leaves, and large handsome flowers. They are confined to Tropical and Temperate regions, the most beautiful species being found in the Tropics. Our yellow water-lily (*Nuphar luteum*) and white water-lily (*Nymphæa alba*) are well-known. Of foreign species we may note the lotus-flower (*Nelumbium speciosum* of the Ganges and Nile; was held sacred by the Hindoos and Egyptians) and the *Victoria regia*. The latter, which grows in still waters along the Amazon and other rivers of Tropical South America, is the largest of all water-plants. Its leaves may reach six feet in diameter; they are circular in shape, green above, red and prickly below. The flowers are white, strong perfumed, and may measure as much as eighteen inches across.

XI.

RHŒADINÆ.[1]

The *Rhœadinæ* or Poppies are choripetalous dicotyledons with superior ovary; the stamens and both floral envelopes are inserted on the receptacle. Flowers tetramerous, with two or four sepals and four petals, an arrangement highly characteristic. The ovary is composed of two or many carpels, and is few or many seeded. Stamens either indefinite and free, or few and partly united, or, again, six free, of which the two outer (episepalous) are short, the four inner (epipetalous) long. (This last arrangement is characteristic of Fumariaceæ.) The Rhœadinæ form a link between the Polycarpicæ and other classes. Familiar orders are as follows:—

(53.) *Papaveraceæ* (*Poppies*).—Calyx composed of two carpels, caducous; corolla regular; petals four, in whorls of two (Fig. 246, III., VIII.), the outer alternating with the sepals, the inner opposite to them. Stamens indefinite, ovary composed of many (II.), or one or two (VI., VII.) carpels. In the former case the ovary is incompletely many-celled, many-seeded, with ovules attached to parietal placentæ. In the latter case the ovary is one-celled, with ovules arranged in four rows. Fruit, in the former case, a capsule, with porous dehiscence (I.), in the latter case a siliqua (IV., VI.).—[60.]

[1] Latin, *rhœas*, a poppy (from the Greek word for the name given to the plant by Theophrastus; *ροιας* is derived from *roia* or *roa*, the pomegranate, so called because of its colour).

The Papaveraceæ are herbs of the North Temperate Zones; they contain white or yellowish milky juice. Common genera are the corn poppy (*Papaver*) and the celandine (*Chelidonium*). The narcotic opium is obtained from the milky juice of the unripe capsule of *Papaver somniferum*.

FIG. 246.

Papaveraceæ.—I.-III. Corn poppy (*Papaver Rhœas*). I. Stamens and capsule; twice nat. size. II. Cross section of capsule, four times enlarged. III. Diagram. IV.-VIII. Celandine (*Chelidonium majus*). IV. Flower; V. Bud; VI. Siliqua, nat. size; VII. Part of the same enlarged; VIII. Diagram. *b* Flower-stalk, *k* Calyx, *bl* Petals, *s* Stamens, *f* Ovary, *n* Stigma, *k* (VIII.) Cells of the ovary, *c* Ovules.

(54.) *Fumariaceæ* (*the Fumitory Order*).—Sepals two, small or absent; corolla irregular; petals four, in two whorls of two, one petal of the outer whorl spurred (Fig. 247 and Fig. 82). Stamens six, in one whorl, alternating with the sepals, united in threes (in some foreign species stamens four, distinct). Fruit a several-seeded siliqua, or a one-seeded nut.—[100.]

A small order; delicate smooth herbs of Europe, North Africa, North Asia, and North America. *Corydalis* (fruit a siliqua) and Fumitory (*Fumaria*, fruit a nutlet) are found wild in this country. *Dicentra* (Dielytra) *spectabilis* is a favourite garden plant.

(55.) *Cruciferæ* (*Cross-Flowers*).—Calyx of four sepals, in two whorls of two, often caducous; corolla regular, petals four (one whorl); stamens six, in two whorls, the outer with two long stamens, each opposite to one of the inner sepals; the inner with four short stamens, each opposite to one of the four petals. Ovary composed of two carpels; carpels opposite the outer sepals, containing four rows of ovules, divided by a false dissepiment (*replum*, Fig. 248). Fruit a siliqua, dehiscing from below upwards (comp. Fig. 129), or a nut.—[1200.]

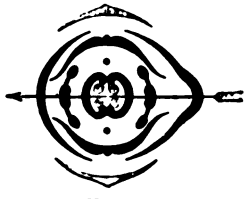


FIG. 247.
Corydalis bulbosa.

The Cruciferæ form a large and well-defined order common to both Temperate regions, but especially well represented in the Northern Hemisphere; there are also Arctic and Alpine varieties. We have in this country some ten families, chiefly to be distinguished from one another by differences in the fruit and seed, but a more minute consideration of these is unnecessary in this work. Home representatives of this order are—*Nasturtium* (water-cress), *Arabis*, *Cardamine*, *Hesperis*, *Sisymbrium*, *Erysimum*, *Brassica* (which includes cabbage, turnip, rape, or colza, &c.), *Sinapis* (mustard), *Alyssum*, *Draba*, *Cochlearia* (scurvy-grass), *Thlaspi*, *Lepidium* (cress), *Capsella* (shepherd's purse), *Isatis* (woad), *Raphanus* (radish), &c. *Cheiranthus Cheiri* (the wallflower), *Matthiola incana* and *M. annua* (stocks) are cultivated species.

FIG. 248. Typical flower of Cruciferæ.

XII.

CISTIFLORÆ.

The *Cistifloræ* are choripetalous dicotyledons with superior ovary. Calyx, corolla, and stamens are inserted on the receptacle. Sepals five, petals five, in two whorls, alternating with each other; stamens opposite the sepals, as many as the petals and sepals, or more numerous and variously arranged. Ovary usually composed of three carpels (Fig. 99, II.), one-celled, placentation parietal (the characteristic feature of the class). The class includes numerous small orders, the most important of which is the order—

(56.) *Violaceæ* (*Violets*).—Flowers symmetrical; stamens five, inserted on a disk; fruit a capsule (Fig. 249).—[240.]

FIG. 249. Dog violet (*Viola canina*).

The Violaceæ are found in all parts of the world (their tropical representatives have regular flowers); in this country they are herbs. The native genus *Violet* (*Viola*), includes a number of well-known species. The *Droseraceæ* (*Sundews*) and the *Cistaceæ* (rock-roses) are related.

XIII.

COLUMNIFERÆ.[1]

The *Columniferæ* are choripetalous dicotyledons with superior ovary. Sepals, petals, and stamens are inserted on the receptacle.

[1] Latin, *columna*, a pillar; *fero*, I bear.

Calyx and corolla regular, pentamerous, alternate; an epicalyx is also frequently present. Stamens always numerous, united into one, three, or several bundles (Fig. 96, II.). Ovary three or five celled, with three or five free styles. Fruit a capsule, rarely a berry (Fig. 250).—[210.]

(57.) *Hypericaceæ* (*St. John's Worts*).—Calyx four or five lobed, æstivation quincuncial and convoluted. Petals five (or four). Stamens many, united to form three or five bundles (Fig. 96, II.). Ovary three or five celled, with three or five free styles. Fruit a capsule, rarely a berry (Fig. 250).—[210.]

The Hypericaceæ form the connecting link between the Cistifloræ and the Columniferæ, being reckoned by many botanists as belonging to the former. Our indigenous Hypericaceæ are mostly herbs or shrub-like plants, but in the Tropics the order includes several trees, with simple, undivided, opposite leaves, whose surface is dotted with transparent glands. One genus—*Hypericum* (flowers yellow)—represents the order in this country. *H. calycinum*, an Oriental species bearing large handsome yellow flowers, is a favourite garden plant.

FIG. 250.

St. John's wort (*Hypericum perforatum*).

(58.) *Tiliaceæ* (*Limes or Lindens.*)—Calyx of five or four sepals, æstivation valvular (Fig. 251, I.). Petals five or four likewise. Stamens numerous, free, or united into several bundles. Ovary usually five-celled, with one style (II.). Fruit nut-like, mostly indehiscent, often by suppression one-celled and one-seeded.—[330.]

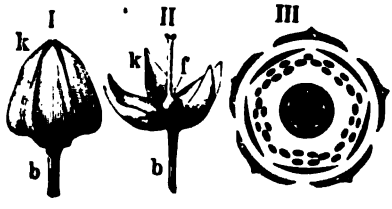


FIG. 251.

Linden (*Tilia parvifolia*).—I. Bud; II. Calyx and ovary; III. Diagram; *b* Flower-stalk; *k* Calyx; *f* Ovary (I. II. twice nat. size).

The Tiliaceæ are trees or shrubs with scattered leaves; they are found mostly in the Tropics, a few genera only in Temperate regions. In this country the lime-trees (*Tilia parvifolia* and *T. grandifolia*) are familiar.

(59.) *Malvaceæ* (*Mallows*).—Calyx rarely three, usually five lobed, valvate in æstivation; an epicalyx is often present (Fig. 71, I.). Petals as many as with the lobes of the calyx; æstivation imbricate. Stamens numerous, united into a

single bundle, the united filaments forming a thick tube (the column, Fig. 96). Ovary composed of many carpels, which are sometimes not perfectly united, each cell one or several seeded (Fig. 252).—[700.]

Our indigenous mallows are herbs or shrub-like plants, but in the Tropics, their original home, the class includes many trees bearing beautiful flowers. In this country the class is represented by the mallow (*Malva*) and the hollyhock (*Althæa rosea*), while *Hibiscus* and *Abutilon* are favourite greenhouse plants. From the cotton plant (*Gossypium*) we obtain the cotton of commerce, and the fine hairs covering the seeds of the cotton-tree (*Bombax*) are also utilised in the manufacture of cotton. A cotton-plant (*Gossypium herbaceum*) is now being largely cultivated in South Europe.

FIG. 252.
Mallow (*Malva sylvestris*).

XIV.

GRUINALES.[1]

The *Gruinales* (crane's-bills) are choripetalous dicotyledons with superior ovary. Calyx, corolla, and stamens are inserted on the receptacle. All the organs of the flower are pentamerous (very rarely tetramerous), and form five whorls (two whorls of stamens, rarely only one); sepals and petals usually free, stamens united to form a single bundle; the stamens are either united throughout the whole length of their filaments, or only at the base. Ovaries five, united, each with two ovules, one of which is suppressed, so that the fruit is one-seeded. One order is important:—

FIG. 253.
Crane's-bill (*Geranium pratense*).

(60.) *Geraniaceæ (the Crane's-bills)*.—Characteristics as above.

Indigenous genera are *Geranium* (crane's-bill) and *Erodium*; many species of *Pelargonium* are favourite garden and greenhouse plants.

XV.

ÆSCULINÆ.[2]

The *Æsculinæ* (horse-chestnuts and maples) are choripetalous dicotyledons with superior ovary. Sepals, petals, and

[1] Latin, *grus*, a crane.
[2] Latin, *æsculus*, the horse-chestnut (seemingly believed by the Ancients to be a species of oak).

stamens inserted in the receptacle. Calyx and corolla pentamerous, stamens also originally pentamerous, but as a rule several members of the staminal whorl are suppressed; the ovary is two or three celled, few-seeded. Two orders.

(61.) *Sapindaceæ* (*the Horse-Chestnut Order*).—Calyx pentamerous; sepals united; corolla irregular; stamens seven, of unequal length (Fig. 254). Ovary three-celled, each cell two-seeded. Fruit a one to three seeded, dehiscent, fleshy capsule.—[700.]

Fig. 254. Horse-chestnut (*Æsculus Hippocastanum*).

Fig. 255. Samara of the maple (*Acer platanoides*).

Fig. 256. Maple (*Acer Pseudo-Platanus*).

Trees of the warm and North Temperate regions, with beautiful palmate leaves; the two most important species grown in this country, are the horse-chestnut, *Æsculus Hippocastanum* (with white flowers, a native of Persia), and *Æsculus carnea*.

(62.) *Acerineæ* (*the Maple Order*).—Calyx usually five (rarely four, six, or nine) lobed; petals as many as the lobes of the calyx, and alternating with these, all of like size and shape, and of the same greenish colour as the calyx. Stamens usually eight, inserted on a thick, fleshy disk, which supports centrally the two or three celled winged ovary. Cells of the ovary two-seeded. Fruit a samara (Figs. 255, 256).—[50.]

Lofty trees of the North Temperate Zone, with opposite, usually palmately-lobed leaves; the wood of all the species is firm and tough. The sap of the North American *sugar maple* (*Acer saccharinum*) is manufactured into sugar. *Acer campestre*, *A. platanoides*, *A. Pseudo-Platanus*, are species found in this country; *A. Negundo* and *saccharinum*, from North America, and *A. monspessulanum*, from South Europe, are occasionally introduced by horticulturists.

XVI.

FRANGULINÆ.[1]

The *Frangulinæ*, or Buckthorns, are choripetalous dicotyledons with superior ovary. Sepals, petals, and stamens inserted on the receptacle; flowers always regular; stamens five, epipetalous; ovary mostly two-celled, the cells one or two seeded. Two orders.

(63.) *Rhamnaceæ* (*the Buckthorn Order*).—Floral envelopes small, penta-, rarely tetramerous; stamens five (four), opposite to the petals. Ovary two to four celled, cells one-seeded; style one; stigmas equal in number to the cells of the ovary. Fruit baccate (Fig. 257).—[430.]

FIG. 257. Alder (*Rhamnus Frangula*).

FIG. 258. Vine (*Vitis vinifera*).

Shrubs of tropical and temperate regions; *Rhamnus catharticus* (the buckthorn), and *R. frangula* are familiar home species.

(64.) *Ampelideæ* (*the Vine Order*).—Calyx entire or slightly four to five toothed; petals five (four); stamens as many as the petals, and opposite them. Ovary two-celled, each cell two-seeded; one style and one stigma; fruit a berry (Fig. 258).—[250.]

Indigenous to the warm and temperate regions; climbing shrubs, bearing tendrils and lobed or palmate leaves. To this order belongs the common vine (*Vitis vinifera*), perhaps originally a native of Temperate Europe. About 1300 species of *Vitis* have been artificially produced, and are now widely cultivated in Europe. Various species of *Ampelopsis* (Virginian creeper) are frequently seen in our gardens.

[1] Latin, *frangula*, the buckthorn.

PART III.

PHYSIOLOGICAL BOTANY.

Flowers and Insects.

In Part I. we considered the plant as a whole, then each set of organs in particular, the mutual relations of the various organs, and the forms which each may assume in different plants.

In Part II. we examined the more important groups of the so-called higher plants or *Phanerogams*. From this examination we gained a knowledge of the peculiar forms of floral structure, &c., characteristic of those groups, and saw how the same organs may appear in different species under the most diverse aspects.

As yet, however, nothing has been said as regards the functions of those organs. Here and there something of them may have been hinted at in a casual manner, but even these hints only applied to such general functions as are universally known. We may have said, for example, that it is the function of the root to absorb liquid nourishment, or that the flower only exists for the development of the fruit, but nothing further. To take another example: although we may now know a good deal as regards the shape and general appearance of the foliage leaves, we have learned absolutely nothing of the duties which they fulfil during the life of the plant.

A knowledge of the peculiar functions of an organ is, however, just as important as a knowledge of its peculiar form. Accordingly, we shall now proceed to take up in Part III. the *Functions of the Flower*. We shall thus have an opportunity of making use of the knowledge we have already acquired, while adding to it new facts regarding the uses of the various sets of organs. We shall see, moreover, that the form exhibited by a particular flower or a particular organ is assumed in accordance with the functions it has to perform.

I.—FERTILISATION.

A flower consists, as we already know, of the *floral envelopes*, the *stamens*, and the pistil. Of these the *non-essential* parts are the floral envelopes; the *essential*, the stamens and the pistil.

The stamens and the pistils are either found together in the same flower (*hermaphrodite flowers*, ☿), or the stamens are confined to one flower (*male flower*, ♂), the ovary to another (*female flower*, ♀). When male and female flowers grow together on the same individual, the plant is said to be *monœcious*; when the male flowers are confined to one individual, the female to another, the plant is said to be *dicœcious*. We must note also that certain species bear flowers, which have neither stamens nor pistil (*neuter flowers*), as is the case with the Guelder rose, *Hydrangea*, &c., but such flowers never develop fruit. The flowers of any plant are never *exclusively* neuter, but are partly neuter, partly hermaphrodite or unisexual.

1.—*The Floral Envelopes.*

It by no means follows from what has been said as regards the floral envelopes being non-essential parts of the flower, that they are in any way to be regarded as *superfluous*. Thus it is easy to see, for example, that the beautiful blue corolla of the campanula serves as a protective covering for the stamens and pistil which it conceals. It shelters the internal organs against wind and weather. It has been discovered that pollen is soon rendered useless by the least exposure to damp, and in the case of the bellflower we see how well calculated the corolla is to prevent the occurrence of such a casualty. The figure shows the flower in its natural position on the upright stem (*a*). The flower-stalk (*s*) bends over from the stem, so that the throat of the flower (*b*) is directed downwards. The outer surface of the flower being convex, any rain that may fall on it simply forms into drops and trickles off, none being permitted to make its way to the interior of the flower.

FIG. 259.

Flower of *Campanula Trachelium* in its natural position (nat. size). *a* Stem; *s* Flower-stalk; *b* Corolla; *v* Bract; nat. size.

2.—*The Stamens.*

We already know that a stamen consists of two parts, the *filament*, which is crowned by two small, mostly yellow, sac-like bodies—the *anther*. We saw further that, when the flower is in bloom, the anthers open by a longitudinal or transverse slit, or by pores, through which the *pollen* or yellow dust contained in the anther is shed. The structure of an anther may be well seen in a thin transverse slice taken from an anther of sufficient size (say of the fritillary). The section must be placed between two pieces of glass and examined with a lens. In the middle of the slice will be seen a thin round space, with a dark centre (*a*), the *transverse section of the filament*. On either side are the anthers (*b b*). They are composed of a membranous outer wall (*w*) enclosing a cavity (*e*). Previous to the opening of the anthers this cavity is filled with pollen grains (*s*). There are usually thousands of pollen grains in each anther. When the stamen is ripe, the anther opens along a notch or suture, which runs throughout its whole length (the section passes through it at the point *c*). This is the *dehiscence* of the anther. Having separated, the free edges of the suture curl outwards or inwards, leaving an opening (as at *d*) through which the pollen may pass out. As the pollen grains are in many cases rather sticky, they usually adhere to the external surface of the anther (Fig. 95, I.-III.).

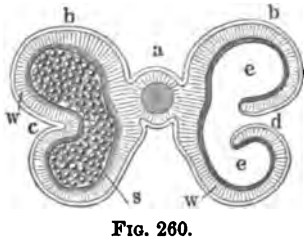


FIG. 260.

Transverse section of the anther of fritillary (*Fritillaria imperialis*); fifteen times enlarged. *a* Filament; *b b* Anthers; *c* Suture; *d* Slit; *e* Internal cavity of the anther; at *s* filled with Pollen; *w* Outer wall (somewhat diagrammatic).

3.—*The Pollen.*

When looked at through the microscope, pollen is seen to consist of a large number of small rounded bodies, all of pretty much the same size.

Let us compare the pollen grains of several different plants (Fig. 261). The pollen grain of the hazel (I.) is rounded in shape, smooth on the surface, but with three small protuberances

(*k*), at one end of each of which is a small round orifice. In other plants, *e.g.*, hazel-wort (III.), the surface of the pollen grain is not quite smooth, but is dotted with little wart-like prominences. Others again, *e.g.*, the colt's-foot (II.), have the surface of the pollen grain beset with strong prickles. In the hepatica (IV.) the pollen grain is not rounded but elliptical in shape. Other forms are rare. The pollen of the pines (V.) is well worthy of note. Each grain is slightly elongated, and has at the sides two small, delicate, membranous sacs, on the surface of which a dark network is seen. These sacs (*air-sacs*) are filled with air, and serve to support the grain in the atmosphere, so that it may be carried a long way by the wind.

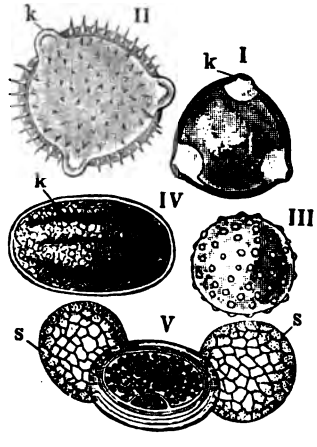


FIG. 261.

Pollen Grains.—I. Hazel (*Corylus Avellana*); II. Colt's-foot (*Tussilago Farfara*); III. Hazel-wort (*Asarum europæum*); IV. Hepatica (*Hepatica triloba*); V. Pine (*Pinus sylvestris*), — magnified 300 diameters; *s* Air-sacs.

In some cases (*e.g.*, the pollen of the Orchids and Asclepiads), the pollen grains do not separate after the dehiscence of the anther, but remain bound together by a number of elastic threads. They are then said to form *pollen-masses* or *Pollinia*.

The number of pollen grains produced by a single flower is enormous, as any one will readily admit who has shaken a hazel-bush when in blossom. The individual grains are almost invisible to the naked eye, yet when the catkins are shaken the air is filled with a cloud of whitish yellow dust,—the pollen. If we catch a little of it on a piece of black paper, we see the grains as small yellow dots, but it is impossible to count them. It has been calculated, however, that a single flower of hibiscus produces about 4900 grains, one of dandelion 243,600, one of the peony 3,654,000.

There is an apparatus called the micrometer, by which, under the microscope, we can measure the actual size of a pollen grain. In the following table we have the diameter of the pollen of a number of early spring flowers, &c. :—

Hazel (*Corylus Avellana*), ...	·03 mm.
Speedwell (*Veronica hederæfolia*), . . .	·04 mm.
Chick-weed (*Stellaria media*), . . .	·04 mm.
Colt's-foot (*Tussilago Farfara*), . . .	·04 mm.
Asarabacca (*Asarum europæum*), . . .	·04 mm.

Hellebore (*Helleborus viridis*), . . .	·04 mm.
Hepatica (*Hepatica triloba*), ...	·06 mm.
Banana (*Musa ferruginea*), ...	·12 mm.
Strelitzia (*Strelitzia Reginæ*), ...	·13 mm.

In most of the cases above cited the diameter of the pollen grain is ·04 or $\frac{4}{100}$ millimetre. There are thus 25 to the millimetre. The pollen grains of the banana are comparatively large—8 to the millimetre.

The pollen shed from the anthers, whether sticky or dry, sooner or later reaches the stigma. Of the manner in which this is accomplished we shall learn more hereafter.

The Stigma.

The stigma is found at the summit of the ovary. Either it lies directly on the summit, or, as more usually happens, the ovary is prolonged above into a delicate stalk, at the point of which is the stigma. The stigma, as a rule, is easily recognised. In many cases it is made conspicuous by its shape, *e.g.*, in Weigelia (Fig. 58), where it forms a knob-like prominence. But even when its shape is not at all conspicuous, it may be distinguished from the ovary and the style by its *rough surface*. While the ovary and style are smooth, the stigma is entirely covered by irregularities, or by long, stiff, usually greyish, hairs (Fig. 262). In the figure I. and II. represent the stigma of hazel-wort. The style (*g*) is perfectly smooth, and divides into

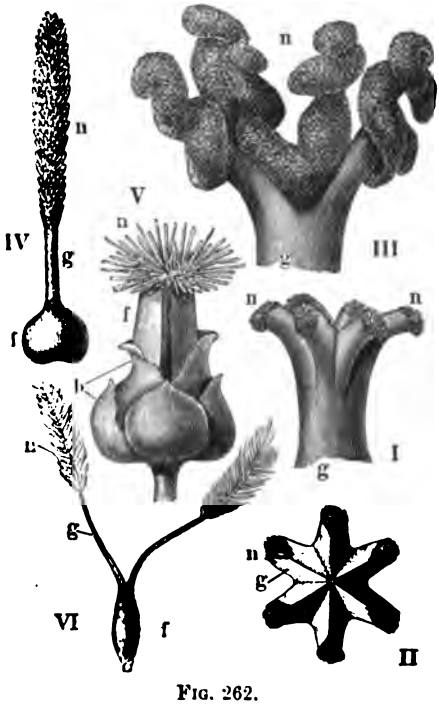


Fig. 262.

Stigmas.—I. II. Asarabacca (*Asarum europæum*), viewed from the side and from above; four times enlarged; III. Begonia (*Begonia cucullata*), six times enlarged; IV. Plantain (*Plantago major*), five times enlarged; V. (*Triglochin maritimum*), ten times enlarged; VI. (*Arundo Donax*), four times enlarged; *b* Floral envelopes; *f* Ovary; *g* Style; *n* Stigma.

air branches at its upper end; each of these branches is beset with hairs at its extremity (*n*), and these hairy parts are the six stigmas. The stigmas of the begonia (III.) are similar. The thick, short, smooth style (*g*) divides into six branches, each of which has a large, rough, twisted stigma (*n*); the stigmas are united in pairs at the base. In *Plantago* (IV.) the greater part of the simple, unbranched style (*g*) is occupied by stigma (*n*), which forms a stiff brush-like body, covered with short thick hairs. Stigmas having very long hairs are those of *Triglochin* and the grasses. The stigma (*n*) of *Triglochin* (V.) lies directly on the summit of the long triangular ovary (*f*). It consists of a number of distinct, stiff, rather rigid hairs, which radiate from the centre in all directions. The stigmas (*n*) of the grasses (*e.g.*, of the reed *Arundo Donax*, VI.), have a feathered arrangement of the hairs.

Supposing that a pollen grain lights on the stigma, it is detained there by the rough hairy surface. If the hairs are long, the arrangement for detaining the tiny pollen grain is particularly complete. Moreover (and this is especially so in cases where the hairs are short), a viscous fluid exudes from the stigma and covers its whole surface, so that the pollen grain, often sticky of itself, cannot but adhere. Once on the stigma, the pollen grain is a permanent prisoner, not even the most violent shaking of the plant by the wind being sufficient to set it free.

5.—*Fecundation.*

The pollen grain having arrived at the stigma, let us now try to follow its further progress. If we watch it for some time we notice certain very remarkable changes taking place. With the aid of a microscope we can see projecting from the pore in one of the protuberances a slender process, the *pollen-tube* (see Fig. 263). The figure represents a pollen grain of willow-herb magnified 600 diameters. The grain, like others already mentioned, is almost globular in shape, having three protuberances (*k*), each very thin at the apex. It is surrounded externally by a double coat (*a i*), the internal cavity being filled with a viscid substance (*t*), which contains a large number of minute granules—the protoplasm. The pollen-tube emerges as a short, colourless process (*s*) of the protoplasmic contents (*t*) of the grain, covered by a

delicate continuation of the inner coat. Gradually the pollen-tube increases in length, penetrates the stigma, and becomes deeply imbedded in its tissues. The longer it grows the further it pushes its way down through the stigma and style, until at last it reaches the interior of the ovary. Here it meets with the ovules, with one of which it becomes united. The ovule contains a cavity filled with fluid, the so-called *embryo-sac*. The pollen-tube impinges upon the embryo-sac, penetrates it, and communicates some portion of its contents. *Only after the contents of the pollen-tube have mingled with those of the embryo-sac is the latter in a position to develop the embryo of a new plant.* If this mingling does not take place, the ovule cannot become a seed; on the contrary, it speedily ceases to grow, and shrivels up or disappears.

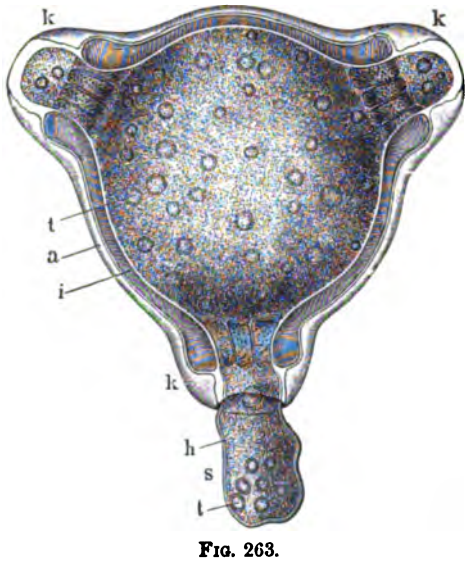


FIG. 263.

Pollen grain of willow-herb (*Epilobium angustifolium*), magnified 600 diameters. *k* Pore; *a* Outer; *b* Inner coat; *s* Pollen-tube; *h* Coat of pollen-tube; *t* Protoplasmic contents.

The mingling of the contents of the pollen-tube with those of the embryo-sac is the essential feature of the process of fecundation.

6.—*Cross Fertilisation.*

Many plants, as we already know, are *hermaphrodite*, *i.e.*, their flowers possess both stamens and ovary. One would naturally suppose that in such flowers the pollen is simply shed on the stigma, where the grains develop their pollen-tubes, and the process of fertilisation completed as already described, the organs brought into contact being those *of the same flower*. But in many instances this is by no means the case. It has

been shown by experiment that, as a rule, the pollen of a given flower is incapable of fertilising the ovules of that flower. *Usually fertilisation is only effective when the pollen is brought to the ovule from another flower of the same species.*

The following experiment suffices to show that the pollen of many plants produces no effect when laid on the stigma of the same flower. Two tulips in separate pots were brought into the house shortly before the flowers opened. The flower-buds were isolated by tying large gauze bags over each. When full-blown the covering was removed from one flower, and by means of a fine camel's-hair brush, a little of the pollen from one of the ripe stamens was laid on the stigma. Pollen from the same stamen was then laid on the stigma of the other tulip, after which both plants were again enveloped in their gauze coverings and left undisturbed. The result was that the ovary fertilised with the pollen of the other flower, developed into a perfect fruit containing seeds capable of germinating, while that of the flower fertilised with its own pollen formed a stunted capsule, with seeds incapable of germinating.

The conveyance of pollen from the stamens to the stigma being termed *fertilisation*, the conveyance of the pollen to the stigma of the same flower is distinguished as *self-fertilisation*, or *close-fertilisation;* the conveyance of pollen from the stamens of one flower to the stigma of another as *cross-fertilisation*. In the last case two flowers are said to *cross* with each other.

We may therefore express the result of the above experiment thus:—*Cross-fertilisation produces the greatest number of seeds capable of germinating, while self-fertilisation tends to produce few or no seeds capable of germinating.*

It has been shown by experiment that even in cases where seeds capable of germinating *are* produced by self-fertilisation, there are certain important differences between them and seeds produced by cross-fertilisation.

1. Self-fertilised ovaries on the whole produce *fewer* seeds than cross-fertilised ovaries of the same plant.
2. The seeds produced by self-fertilisation are on an average smaller and lighter than those produced by cross-fertilisation.
3. Plants which spring from seed which is the result of self-fertilisation are on an average smaller and weaker than those produced from seed which is the result of cross-fertilisation. The former also produce fewer seeds than the latter.

The correctness of these generalisations is easily shown. If we treat a number of plants after the manner described in the last experiment, fertilising some with their own pollen, some with the pollen of another individual of the same species, we can in due time

collect the ripe seeds from the two sorts and compare them. We shall then see that the cross-fertilised flowers have produced more and heavier seeds than the self-fertilised. If an equal number of seeds be selected from each sort, and sown in a flower-pot in such a way that each sort will be kept apart, there will be a marked difference between the two sets of seedlings thus obtained. The seedling produced from the seeds of the cross-fertilised flowers will be much stronger than those produced from the other, a fact which becomes more and more evident with the continued growth of the plants.

Thus, in the struggle for existence, seeds which are the result of cross-fertilisation always tend to survive those which are the result of self-fertilisation.

In nature, self-fertilisation is not unknown, but in many plants it only occurs if cross-fertilisation has not taken place. There are, however, some few plants in which self-fertilisation seems the rule. In most species regular or occasional cross-fertilisation—crossing between different individuals—takes place. In plants possessing male and female flowers this is a matter of course. But even among hermaphrodite flowers cross-fertilisation is common, nay, as we shall see further on, in many cases self-fertilisation is absolutely impossible. *Pollen is conveyed from one flower to another, either by the wind or by the intervention of animals, especially of insects.* How this is effected we shall see in the next chapter.

II.—WIND-FERTILISATION.

In many plants the transference of the pollen of one flower to the stigma of another (crossing) is accomplished by the wind. The extreme minuteness and lightness of the pollen grains enable them to keep afloat in the air for a long time. The wind thus frequently carries the pollen to considerable distances, where it may alight on the flowers of other individuals of the same species, thereafter remaining adherent to their stigmas. All plants fertilised by the wind are called anemophilous or wind-fertilised plants.

There are also certain species of plants in which the transference of pollen is effected by means of water. Such, for example, is the well-known Vallisneria (*Vallisneria spiralis*). This is a dioecious plant with bright green, linear, submerged leaves. It is a native of Italy, where it grows at the bottom of shallow streams. The female flowers open at the surface of the water, being borne on long spiral pedicels. The

male flowers break off under water from the parent organism, float to the surface, open there, and are carried by the current to the female flowers, which they fertilise.

The arrangements found in anemophilous plants for effecting cross-fertilisation, and for rendering self-fertilisation almost impossible, are as follows:—

(1.) Wind-fertilised plants flower for the most part in spring, at a time, that is, when high winds prevail.

(2.) The quantity of pollen produced is enormous.

(3.) The pollen grains are dry, not viscid.

(4.) The inflorescences, flowers or stamens, are so placed as to be easily shaken by the wind.

(5.) The stigma is large, exposing to the pollen grains that may be flying about in its vicinity a very broad and hairy surface.

(6.) The position of the stigma in the flower is such as to be easily reached by the floating pollen grains.

(7.) The floral envelopes are small, and do not cover stamens and stigma.

(8.) Many wind-fertilised plants are dicœcious, one individual bearing only male, another only female flowers.

(9.) In those wind-fertilised flowers which are moncœcious, or which bear hermaphrodite flowers, self-fertilisation in the same flower, or in the flowers of the same individual, is commonly prevented by the fact that their stigmas and anthers ripen at different times.

Arrangements for ensuring Cross-Fertilisation in Anemophilous Plants.

(1.) The majority of our native deciduous trees are wind-fertilised. To this class belong, for example, the catkin-bearing trees (p. 134), the birch, the hazel, the aspen, the poplar, the elm, the oak, and others. In these the flowers develop before the leaves, so that the trees are in full blossom while the leaves are yet in the bud. Only in a few cases are flowers and leaves developed simultaneously.

The trees above mentioned flower very early in the year—the hazel in February and March; the aspen, the poplar, the black poplar, the elder, and the elm, in March or April; the beech,

the hedge-beech, the birch, and the oak in April or beginning of May. At this time high winds are common, and the trees being leafless, the wind can easily shake out the pollen from their anthers and carry it away. If the trees were then in full leaf, this could not be so readily accomplished, for the wind could not penetrate the foliage so as to reach the stamens thus protected. Moreover, the pollen, once shaken out, would simply fall upon the leaves, there to remain and wither uselessly. Finally there would be a great risk of the pollen never reaching the stigmas, were they also concealed beneath a mass of foliage.

(2.) *Quantity of Pollen.*—In the case of the anemophilous plants, the quantity of pollen produced by a single flower is enormous. From a single blossom we frequently get a quantity sufficient to fertilise over a thousand ovaries. Suppose a plant of this kind to bear as many female as male flowers,[1] then $\frac{999}{1000}$ths of all the pollen produced might go to waste, if only the remaining $\frac{1}{1000}$th were equally distributed over the stigmas of the female flowers. It is very evident that in the course of transport by the wind much pollen unavoidably gets lost. In the great majority of cases the pollen never reaches a stigma at all, but, falling on whatever surface may present itself, is simply wasted. Were it not for the enormous quantity of pollen produced, fertilisation could not be effected to nearly such an extent as takes place under existing arrangements.

(3.) *Characteristics of the Pollen Grains.*—The grains of pollen, in the case of the anemophilous plants, are on the surface even, smooth, and dry (Fig. 261, I.). When shaken out of the anthers by the wind, they therefore do not adhere to each other, but separate and float singly in the air. The anemophilous plants have *dusty pollen.* Had the grains of pollen a viscid surface, a number of them would stick together, and such an aggregation would, by reason of its greater weight, fall so much sooner to the ground, and so fail in its function of fertilisation. Most of the anemophilous plants, moreover, having but one-seeded ovaries, a single pollen grain reaching the stigma often suffices to effect fertilisation. By the adhesion, therefore, of several pollen grains, the quantity of fertilising material would only be reduced.

[1] The male flowers, however, usually far exceed the female in numbers.

Among the anemophilous plants the conifers have pollen grains, which are provided with definite organs for effecting transport (the pines, for example, Fig. 261, V. *a*, p. 165). Their surface is greatly enlarged by means of delicate hollow air vesicles, by which provision they are enabled to float for a very long time in the atmosphere.

(4.) *Position of Flowers and Stamens.*—The stamens, and of course the flowers, hold such a position on the plant as to be to the utmost degree exposed to the wind. Many anemophilous plants are trees, and for this reason much more accessible to the wind than are herbs rising but a little way above the ground. But irrespective of this point, the position of the flower is such as to cause it to be easily shaken by the wind. Either the whole inflorescence is such that the slightest breath will move it, or that of the individual flowers or stamens is so.

Typical inflorescences of this sort are found in most of the catkin-bearing trees (hazel, birch, poplar, walnut, oak, &c.). The catkin is pendent at the time of flowering (Fig. 113, *a*, p. 65). The common peduncle (the main axis) is very slender, thread-like, and easily set in motion. In other plants, in many grasses, for example (Fig. 114, II.), particular parts of the inflorescence (the spikelets) possess the last-named characteristic in a marked degree. The wild oat-grass (*Avena fatua*), the quaking grass (*Briza media*, Fig. 264), the wind-grass (*Agrostis*)

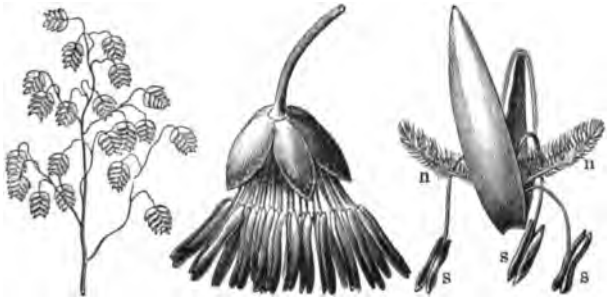


Fig. 264. Fig. 265. Fig. 266.

Fig. 264.—Inflorescence of the quaking grass (*Briza media*); natural size. Fig. 265.—Flower of the meadow rue (*Thalictrum minus*); three times enlarged. Fig. 266.—Flower of the wheat (*Triticum vulgare*); six times enlarged. *n* Stigmas, *s* Stamens.

and others derive their very names from the mobility of their inflorescence. In dog's mercury the clustered inflorescences stand up stiff and straight, as do likewise the filaments

which are longer than the petals of the perianth (Fig. 68, *a*, p. 38). The whole inflorescence forms, so to speak, an elastic rod, which the merest touch will set into quick and long continuing vibrations, in the course of which it rains down showers of pollen.

In other wind-fertilised plants the inflorescence is not itself easily shaken, but the individual florets are set a-quaking by the lightest breeze. They are attached to long, slender, and delicate peduncles, their own weight causing them to assume a drooping position. Examples of plants having this type of inflorescence are sorrel, spinach, rhubarb, and hemp.

In many anemophilous plants, again, both inflorescence and flowers are rigid, the stamens being alone exposed to the influence of the wind. In this case the filaments are long and slender, and have drooping anthers, even when the flower itself grows straight upwards. When the scattering of the pollen depends on the fact that the stamens are easily moved by the wind, the stamens always protrude beyond the floral envelopes. Fig. 265 shows the blossom of the lesser meadow rue (*Thalictrum minus*). The numerous stamens have very heavy anthers, and are considerably longer than the petals of the perianth; like the whole flower, they are directed downwards. In Fig. 266 we have the flower of a grass (wheat, *Triticum vulgare*). In contrast with the one we have just considered, this stands erect. Its three stamens (*s*), however, project far beyond the rim of the perianth, and curve downwards so as fully to expose the long, bright yellow anthers to the wind. The merest touch suffices to set them in motion, causing them to shed from their anthers clouds of yellow pollen.

(5.) *Form of the Stigma.*—The stigmas of wind-fertilised flowers are large, and bristle with long stiff hairs, which diverge from each other, and form an admirable trap for the detention of stray grains of pollen. They, therefore, most commonly assume the appearance of a feather, or thick tuft of feathers (Fig. 262, V. VI., *a*, p. 166), of a whitish or grey colour. In some rare cases the stigma is of a different colour—red, for example, in the hazel.

The stigmas of wind-fertilised plants are usually large, particularly in cases where the flower-stalks bear single or few florets. If, on the other hand, the flowers form into thick clusters, tufts, or heads, the

individual stigmas are smaller. In such a case all the stigmas of the inflorescence collectively offer a sufficiently broad surface for the pollen grains to light on. The flowers on the female catkins of the poplars, for example, are arranged pretty closely; the individual stigmas are therefore in this instance small. The same arrangement is observed in the burr-reed, where the female florets form thick tufts. In a plant similar to the burr-reed—the well-known mace-reed (*Typha angustifolia*)—the individual stigma is quite small, and assumes the form of a diminutive club-shaped knob. Seeing, however, that there are thousands of stigmas ranged close beside each other, composing the well-known mace of the plant, which is four or five inches long, and turns brown after a time, we have here a very broad surface on which the pollen grains may alight. In the case of the female flowers of the conifers (Fig. 111) the florets form a thick inflorescence; stigmas there are none, but when the flowers open the naked ovules are seen each to have on their surface a drop of viscid fluid, which serves to detain any grains of pollen that may reach them.

(6.) *Position of the Stigma.*—As with the position of the stamens, so that of the stigma, in relation to the various parts of the flower, is always such as to render it readily accessible by the pollen. What has been said of the position of the one applies equally well to that of the other. As in the case of the stamen, the stigma also projects beyond the petals, either at the apex, or laterally (Grasses, Fig. 266, *n*).

(7.) *Size of the Floral Envelopes.*—On contemplating the stamens and stigmas of wind-fertilised plants, it is evident that the petals of these plants must of necessity be small; because, were they large—did they enclose (as in the case of many plants not dependent on the wind for fertilisation) the stamens and stigmas—the wind would be quite unable to shake the pollen from the anthers, and just as little able to deposit it on a stigma completely enveloped in a large corolla. The floral envelopes of wind-fertilised plants are small, non-conspicuous, and green in colour. Wind-fertilised plants thus seem to have no flowers in the popular sense (see p. 40). Flowers with large and brightly coloured petals are to be found only in plants which are not wind-fertilised. In only a few wind-fertilised plants are calyx and corolla forthcoming; usually petals and sepals form a perianth, but even that is frequently absent.

(8.) *Dicœcious Plants.*—When it so happens that all the flowers with stamens (♂) are confined to one individual, all the flowers with ovaries (♀) to another, cross-fertilisation must necessarily

occur in every case. The dicœcious state may therefore be described as an arrangement by which self-fertilisation, or a crossing between flowers of the same individual, is rendered impossible.

(9.) *Dichogamy.*—Even, however, in anemophilous plants which are hermaphrodite, or in which male and female flowers are found on the same individual, we frequently find arrangements calculated to prevent self-fertilisation, and to favour cross-fertilisation. Such an arrangement is that whereby intercrossing is secured by a difference in the time of maturity of stamens and stigmas. The stamens are mature when the anthers dehisce, and the pollen is shed. The stigma, again, is said to be mature when it is capable of receiving pollen on its surface, and of being penetrated by the pollen tube. Not till then do the hairs of the stigma become completely developed, nor is the viscid fluid secreted (see p. 167). Only when all these conditions are fulfilled are stamens and stigmas said to be ripe. After stamens and stigmas have been mature for a certain time they begin to get dry. The pollen of the former in that case becomes useless, and the latter are no longer in a fit state to receive the pollen and become fertilised.

By the word dichogamy we describe what occurs when in a ☿ flower, or ♂ and ♀ flowers on the same plant, the stamens and stigmas mature at different times; but we must further distinguish the two following kinds of dichogamy.

(*a.*) The stamens are already ripe while the stigmas are as yet unable to utilise the pollen, and only after the stamens are withered do the stigmas come to maturity. Development of the stamens before the stigmas is called Protandry (sign ♂–♀).

(*b.*) The stigmas are already ripe, while the anthers have not yet opened so as to shed their pollen. When, later on, the stamens ripen, the stigmas have by that time withered. The development of stigmas before the stamens is called Protogyny (sign ♀– ♂.)

If all the individuals of dichogamous species of plants were to flower at precisely the same time, their fertilisation would be altogether impossible. It is, however, well known that in no kind of plant is such the case. If, for example, in a meadow a certain species is well represented, only a few specimens will be seen flowering at the beginning of the season. These have

developed earliest, and are already in bloom, while the majority are yet in bud. Then these come into flower, and finally, after almost all are done flowering, a few stragglers will be found still surviving, and putting forth blossom. This difference in the time of flowering proceeds from many causes. Many individuals are enabled to develop earlier owing to their proximity to water, or to their advantageous situation as regards sun or soil, or the seed from which they spring may have been healthier and better developed, &c. Thus, through this difference in the time of flowering, an exchange of pollen between the individuals of a dichogamous species is ensured.

An example of protogyny (♀-♂) among monœcious flowers we have in the burr-reed (*Sparganium simplex*) (Fig. 267), already mentioned. The flowers are arranged in heads, those at the top of the stalk (♂) being composed solely of male flowers, those further down (♀) solely of female flowers. The female florets are the first to mature, and through the agency of the wind receive the pollen from male flowers of another individual already ripe. After a time the stigmas wither, and now the male flowers develop and shed their pollen, the lowermost first, the upper subsequently. The figure represents a burr-reed in flower, the two heads of female florets already past. Of the male florets the lowermost head is just beginning to shed its pollen, while the four above it have as yet no ripe stamens. In this plant, therefore, the crossing of two flowers of the same individual cannot by ordinary means be effected. On the contrary, only crossing between two flowers of different individuals takes place, quite as in dicœcious plants.

FIG. 267.

Protogynous inflorescence (♀-♂) of the burr-reed (*Sparganium simplex*); nat. size. ♀ Female, ♂ Male flowers.

III.—TRANSFERENCE OF POLLEN BY ANIMALS.

The number of plants in which the pollen is carried to the stigma by the wind is not very large when compared with the number of plants in which crossing is effected by animals. More than all other kinds of animals, it is *insects* which perform the office of conveying the pollen to the stigma of another flower; at all events, in the case of *all* our native non-anemophilous plants. In contradistinction to the anemophilous plants, such are called *entomophilous* or *insect-fertilised* plants.

That animals, and more particularly insects, transfer pollen to the stigma of other flowers is a very remarkable fact. It is all the more remarkable, because these creatures can have no idea whatever of the process of fertilisation, which men themselves have only made out with the aid of the microscope. They effect the transportation of the pollen, then, without having the least notion of the office they are discharging. In insect-fertilised flowers the parts are so arranged that the insects in visiting the blossoms come into contact with the anthers. A portion of the viscid pollen thus adheres to their bodies, which are mostly hairy. If, later on, they come to another flower of the same species of plant, the same part of their body comes into contact with the stigma of that flower, to which, therefore, some of the pollen with which it is covered is of course transferred.

At this point, however, one will be ready to ask, what is the motive prompting the insects to visit the flowers of a plant regularly and frequently? Seeing they have no manner of interest themselves either in the crossing or non-crossing of flowers, it is plain that we must seek some other motive as that to which their visits are to be attributed. Now, within such flowers are materials which are sought after by insects as food, and this it is which occasions them to make the regular visits in question. The greater part of their life is spent in search of such food. The diligence of the bees in gathering honey from the flowers is proverbial, and poets have often rhymed over the butterfly, and how it flits about from flower to flower. Few, however, are aware of the weighty mission in the vegetable world with which these and a whole host of other insects are encharged.

1.—Adaptations in Flowers for Fertilisation by Insects.

Just as in wind-fertilised plants we discovered a series of peculiarities calculated to secure to them the advantage of crossing by the agency of the wind, so also do we find the form and relative position of the parts of insect-fertilised plants adapted in every respect to secure crossing by insects. Such flowers either offer special allurements to the insects, or have peculiarities of structure which subserve the work of crossing by animal agency; and, moreover, have commonly such an arrangement of parts as to exclude those insects which would only consume their honied store without in any way promoting their fertilisation.

A. *Modes of Attracting.*

Insects are attracted to flowers either by their brilliant colour, their perfume, or the store of honey which they contain.

(1.) *Colour.*—The larger a flower is, the more beautiful and brilliant its colour, the greater is its chance of being seen from a distance. Insects are just as sensible as human beings of differences in size and colour, and pass over small and obscure flowers to frequent others of more striking appearance.

The eyes of insects are usually two in number, hemispherical in shape, and each composed of a number of small hexagonal prisms, whence they are said to be compound or facetted. Some insects (bees, for example) have, in addition to those, three simple (supplementary) eyes on the top of the head.

Flowers are rendered conspicuous by the brilliant colouring of the floral envelopes. The coloured part is usually the corolla, more rarely the calyx, or calyx and corolla together. Large floral envelopes are of advantage to insect-fertilised flowers, inasmuch as they give better protection to the parts which they enclose, while their conspicuousness makes the flower all the more striking.

While, therefore, the flowers of wind-fertilised plants are small, inconspicuous, and green in colour (for reasons see p. 175), insect-fertilised flowers are comparatively large and brilliant.

In many plants the *individual* flowers are large and striking, in others conspicuousness is produced by the fact that many flowers are

aggregated so as to form collectively a large *inflorescence*. More rarely it happens that the flowers or clusters of flowers owe their conspicuousness to other parts than the envelopes; for example, the male catkins of the willow, which appear before the leaves, are visible at a considerable distance. Their conspicuousness, which attracts many insects, is due to the beautiful brimstone colour of the anthers. Similarly the conspicuousness of the blossoms of many Australian myrtles is due to the colour of the numerous long filaments. The figures 268 and 269 represent the flowers of two such myrtles (Fig. 268, the *Eucalyptus;* Fig. 269, *Metrosideros buxifolia*). Both possess a funnel-shaped calyx, the lip of which is either entire (Fig. 268) or five-toothed. In both flowers the petals are absent. The numerous stamens arise in a circle from the calyx, and are easily distinguishable at a distance. The colour of the filaments is pure white (in the plants shown in the figure), bright red, or dark blue, and the anthers are also frequently brilliantly coloured. It is the colour of these parts which attracts insects; these plants can easily dispense with a protecting floral envelope, they being indigenous to parts of the Australian Continent, where little or no rain falls during the flowering season.

Brilliantly coloured flowers seem to be as attractive to insects as they are to man. It is no uncommon thing to see a large wasp-like fly (*Syrphus*) hovering long over the brilliant yellow flowers of the mullein (*Verbascum*), with their purple filaments and orange anthers, as if in admiration of this gorgeous display of colour. Equally attractive to a smaller species (*Ascia*) is the beautifully streaked blue corolla of the speedwell (see Fig. 84, *a*). Other insects which live as larvæ on putrid flesh (*e.g.*, the blue-bottle) seem to prefer pale or dark purple blossoms, *i.e.*, such as resemble in some measure the colour of putrid meat.

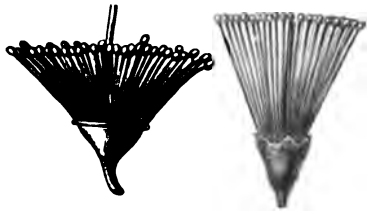


FIG. 268. FIG. 269.

Flowers of Australian myrtles; insects are attracted by the numerous brilliantly coloured stamens (petals are absent). Fig. 268. — *Eucalyptus.* Fig. 269.— *Metrosideros buxifolia;* nat. size.

(2.) *Perfume.*—The perfume of flowers is likewise a means of alluring insects. Many insects, the bees for example, seem to be attracted by the same odours as ourselves. The perfume of the violet, for instance, is a great favourite with these insects. The blossoms of other plants, again, possess the offensive smell of decomposing matters, such as putrid meat, &c., and this is equally attractive to the various species of carrion flies.

Such flowers as are fertilised by night insects are dis-

tinguished by a strong perfume. In their case moths are the chief agents in effecting the transference of pollen. Such plants are also distinguished by large, pale, mostly white or bright yellow flowers, which of themselves render the plants perceptible at some distance; yet, nevertheless, they would be but seldom visited by the moths, were they not attracted by the strong, sweet, penetrating scent. Well-known plants, fertilised by moths, and having pale sweet-scented flowers, are the honeysuckle (*Lonicera Periclymenum*) and the butterfly orchis (*Habenaria bifolia*).

It would appear that insects have the power of perceiving even faint perfumes at considerable distances. Their organ of smell is situated in the antennæ, which in many species are very large, long, and tufted or fringed. In all probability the sense of smell is considerably more developed in many insects than in man.

(3.) *Food.*—The insects in their visits to the various kinds of flowers having always the obtaining of food as their main object; it is necessary for such flowers as would enjoy frequent and continued visits to keep an abundant store for the benefit of their guests. In the eyes of the more intelligent species of insects, colour and fragrance are but slight attractions compared with a plentiful supply of honey, and can only win for flowers possessing them the most occasional visits. That with insects utilitarian considerations preponderate over æsthetic ones, we have abundant evidence, for example, in the case of bees and butterflies. Thus, when a number of conspicuous flowers, some containing, some destitute of honey, stand side by side, the bees will be observed at first to enter either indiscriminately, but, becoming aware by experience of the fruitlessness of their toil, they at length entirely confine their visits to those in which they have found the food they are in quest of.

The foods obtained by insects from flowers are principally (*a*) honey or nectar, and (*b*) pollen.

(*a.*) *Honey* (*Nectar*). — Most insect-fertilised flowers secrete a certain quantity of a clear sweet fluid, which is termed nectar.[1] Essentially nectar consists of water in which sugary matters are dissolved. If, for example, we draw the corolla of the white dead-nettle (comp. Fig. 102, *a*) out of the calyx, and

[1] From the Greek, *nectar*, the drink of the gods in Olympus. The word was applied by Virgil (Georgics, IV., 163, 164), to the honey of bees.

apply the lower end of the tube to the tip of the tongue, the sweetness of the nectar it contains is at once apparent. That part of the flower which is occupied by the nectar is called the nectary. The nectary may be found in very different situations in different plants, being developed sometimes on the corolla, sometimes on the stamens, oftenest, however, in relation to the pistil.

If from the flower of the buttercup we remove one of the five yellow petals (*b*, Fig. 270, I.), we find at the lower end (*claw*) a thickish rounded scale, which forms with the blade a sort of pocket. This is the nectary, and while the plant is in flower it contains a drop of clear watery fluid—the nectar (*t*, II.). In the yellow-rattle (*Rhinanthus*, III.) the nectary is formed by a scoop-shaped scale attached to the bottom of the ovary. This scale contains a globule of honey (*t*). In the case of umbelliferous plants (for instance, *Anthriscus sylvestris*, IV.), the nectary is a two-lobed, thick and fleshy disk (*n*), resting on the surface of the ovary, and situated in the middle of the flower (Fig. 223, *a*, p. 143). The nectary occupies

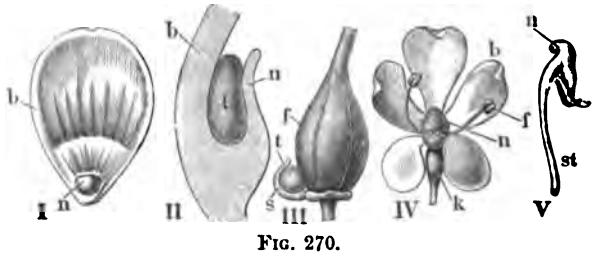


FIG. 270.

Nectaries.—I. Buttercup (*Ranunculus acris*); II. The same in longitudinal section; III. Yellow rattle (*Rhinanthus*); IV. Umbellifer (*Anthriscus sylvestris*); V. Monk's-hood (*Aconitum Napellus*). I. III. three times enlarged; II. eight times enlarged; IV. six times enlarged; V. nat. size. *n* Nectary; *b* Petal; *t* Nectar; *f k* Ovary; *s t* Stalk.

an entirely different position in the flower of the violet (III., Fig. 271). Here two out of the five stamens form the nectary. The anthers (*a a*) are attached to extremely short filaments, and are united. Each of the two lower filaments is continued backwards into a small bright green process (*n*), which lies within the spur of the lower petal, and secretes the honey. In the hellebore (*Helleborus viridis*, Fig. 271, I.), the small green inconspicuous petals are pouch-shaped, and when open are entirely

filled with nectar. A very similar arrangement is found in the columbine (*Aquilegia vulgaris*, Fig. 271, II.), where each of the five dark blue petals forms a funnel-shaped vessel tapering off into a long curved spur. The spur is thickened at its lower end (*n*), and here the honey is secreted. The nectary of monk's-hood (*Aconitum Napellus*, Fig. 270, V.), is yet more singular in shape. Deep within the flower are two long curved filamentous processes, each surmounted by a caplike structure (*n*). The latter is elastic, and in its innermost recesses the honey is secreted. The peculiar nectaries in this case are simply modified petals. Among our native plants the most ornamental nectary is that of the grass of Parnassus (*Parnassia palustris*, Fig. 272), Within the flower, between the petals (*b* I.) and the stamens (*f*) are five peculiarly shaped organs (*s*), each of which is a nectary (II.). The honey is secreted at the lower end, the spot being surrounded by some eleven white stalk-like processes, each surmounted by a yellow knob (*k*).

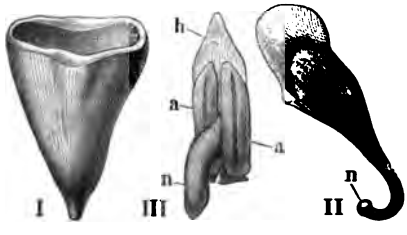


FIG. 271.

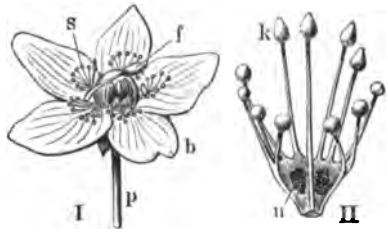


FIG. 272.

Fig. 271.—*Nectaries.*—I. Hellebore (*Helleborus viridis*); II. Violet (*Viola odorata*); III. Columbine (*Aquilegia vulgaris*). I. II. three times enlarged; III. nat. size; *n* Nectary; *a* Anthers; *h* Lengthened connective. Fig. 272.—Grass of Parnassus (*Parnassia palustris*); I. Flower, nat. size; II. Nectary, six times enlarged. *p* Peduncle; *b* Petals; *f* Anthers; *s* Nectary; *n* Portion where nectar is secreted; *k* Glandular process.

From these examples it is sufficiently clear that the nectary may be found in the most various parts of the flower. In the ranunculus, hellebore, columbine, and monk's-hood the nectary is formed by part of the petals, in the violet by the stamens, and in the umbelliferous plants the nectary is borne upon the ovary. Thus the nectary may be represented by an independent organ, or one or other of the normal organs of the flower may be modified so as to form it.

(*b.*) *Pollen.*—The pollen of many flowers is likewise utilised by insects as food. Many beetles, for example, consume the

pollen inside the flower itself; others, like the bees, collect it on certain structures which they possess for the purpose, and bear it with them to the hive. Here they brush it from the body, and mix it with the honey which they have brought home, kneading the whole into a soft granular mass, which they devote to the nourishment of their larvæ. This it is which is called bee-bread. That those plants whose pollen is abstracted in great quantities by insects for the preparation of honey, &c., produce far larger quantities of pollen than is necessary for fertilisation, is a fact sufficiently obvious.

Besides nectar and pollen, some obtain other sorts of food from the flowers they visit. Butterflies, for instance, pierce the delicate wall of the spur of many species of orchids with their long proboscis, and abstract the fluid collected on its inner surface. Other insects devour certain parts of the corolla or the stamens. Such cases are, however, to be looked upon as exceptional—nectar or pollen being the usual attraction.

3.—*Form of the Flower.*

In addition to the powerful attractions of colour, fragrance, nectar, and pollen, many flowers manifest yet other contrivances for securing fertilisation by insects. Thus, for example, we have in insect-fertilised plants, as in wind-fertilised plants, characteristic peculiarities in the pollen or the stigmas. An important feature, too, is the position of the nectary, which is always adapted (especially in relation to the position occupied by stamens and stigmas) to promote the end in view. The various parts of the flower are always so arranged as to afford protection to the nectar against damage by rain, and at the same time facilitate the entrance of insects in quest of food. In fine, the whole structure of the flower is, in many cases, determined by the fact that the plant is dependent upon insect-fertilisation for survival, as we shall see in a later chapter.

(4.) *Peculiarities of the Pollen.*—While the pollen of anemophilous plants takes the form of a fine dust, the individual grains of which are dispersed by the wind (see p. 172), that of most insect-fertilised plants consists of sticky granules, which, by their viscidity, are enabled to adhere to one another when set free from the anthers; first of all, indeed, their tendency is to remain adherent to the anthers themselves. Wind-fertilised

plants might therefore be called "plants having dusty pollen," insect-fertilised plants "plants having viscid pollen." There are but few insect-fertilised plants in which the pollen is not more or less viscid.

We can easily see how important the viscidity of their pollen must be to insect-fertilised plants. If, like that of wind-fertilised plants, the pollen of insect-fertilised plants were dry and dusty, it would be carried away by the gentlest breath of wind, and would be incapable of adhering to the bodies of insects visiting the flower. When, however, each pollen grain possesses a sticky surface it readily adheres to the body of any insect coming in contact with it, and is thus carried to another flower, not even the movement of the insect in flying being sufficient to shake it off.

(5.) *Peculiarities in the Form and Structure of the Stigma.*—Just as in the plants formerly considered, the form and structure of the stigma were seen to be adapted to fertilisation by the wind, so we shall find in the plants now under consideration peculiar adaptations of that organ to fertilisation by insects. In contrast to that of wind-fertilised plants, the stigma of insect-fertilised plants is usually small. The ovary in the former is dependent for fertilisation on stray pollen grains deposited on the surface of its stigma by the wind. For the welfare of the flower, therefore, it is best that that surface should be as broad as possible. In insect-fertilised flowers, on the other hand, the position of the stigma is such that insects entering the flower in search of honey must touch it before reaching the nectary. Some of the pollen brushed off by their hairy bodies from the anthers of other flowers is thus deposited on the stigma, which, the better to detain it, is coated with a sticky fluid. Extent of surface is thus of no importance in the stigma of an insect-fertilised plant, seeing that it must be brushed against by all insects entering the flower.

(6.) *Position of the Nectary.*—In insect-fertilised plants the position of the nectary is always such that an insect, in order to reach it, must come into contact with both anthers and stigma, either at once or in succession. It never happens, for instance, that the nectary is situated at the lip of the corolla, stamens and stigma at the base. Quite the reverse is, in fact, the case. While stigma and anthers reach to or even beyond the rim of

the corolla, the nectary, with its honey, lies hidden in the deepest recesses of the flower. Only in a few instances (with flat, *e.g.*, rotate flowers) does the honey run a risk of being spoiled by rain, and so rendered unattractive to insects. In such flowers we find thick tufts of hair or small scale-like appendages arising from the corolla in such a way as to protect the nectary from all external harmful influences (*e.g.*, many Boraginaceæ).

(7.) *Guides to Insects.*—When an insect attracted by colour or fragrance alights on a flower in which honey is secreted, it is of great importance to the plant that its visitor should find what he is in search of without delay. The shorter the time he spends over one plant the more he can visit in a given time, the more therefore can he fertilise. Accordingly we find that almost all plants which secrete honey are characterised by certain distinguishing marks, all pointing as clearly as possible to the exact spot where their treasure may be found. These marks are to the insect what the finger-post is to the wayfarer, guiding and directing him to his desired destination. They take the form of specks, spots, lines, and streaks on the corolla, distinguished from the general surface of the petals by their colour, and all converging towards one point. That point is the spot where the nectar is to be found. More rarely, brightly coloured hairs arranged on the surface of the corolla, stamens, &c. take the place of the more familiar streaks, spots, &c.

A few examples will best serve to make us familiar with the various markings which serve insects as guides to the honey.

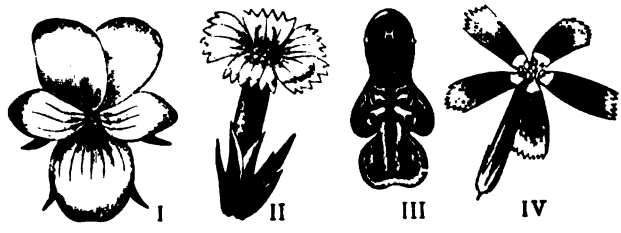


FIG. 273.

Guides to the Honey.—I. Pansy (*Viola tricolor*); II. Carthusian pink (*Dianthus Carthusianorum*); III. Wound-wort (*Stachys palustris*); two times enlarged; IV. Field pink (*Dianthus deltoides*).

In the pansy (Fig. 273, I.), we find a number of straight or curving lines, sharply defined from the general yellow colour

of the petals by their purple or dark blue colour, and all converging towards the centre of the flower. Here we have the entrance to the spur in which the nectar secreted by the two stamens (p. 182) is collected. The case of the pink is somewhat similar. On its five rose-coloured petals are fifteen blackish lines. These all converge to the centre of the flower, like the radii of a circle. Similar markings may be observed in the flower of the speedwell (comp. Fig. 84, *a*), only that here the numerous lines are of dark colour on a ground of bright blue. Light coloured markings on a dark ground occur in the flower of the wound-wort (III.). The flower is of a general dark purplish brown hue; the markings are formed by a number of bright red patches and lines, all pointing to the throat of the flower (see Fig. 86). Very similar are the markings on the hemp-nettle (*Galeopsis versicolor*; see Fig. 86, *a*), only here the colour of the petals is rose pink, the markings dark purple. The field pink (*Dianthus deltoïdes*, IV.), too, has markings which are brighter than the ground colour of the corolla. The petals are of a reddish purple tint, their bases being distinguished by five whitish spots, while over the general surface of each are scattered numerous smaller points, likewise white in colour.

That these markings really conduct the insects to that part of the flower where the honey is concealed is well ascertained. Firstly, the fact has been established by careful observation; and, secondly, it might be inferred from the circumstance that all anemophilous plants, and all such insect-fertilised flowers as are visited by the insects at night, have no special markings. In the case of the anemophilous plants markings would only serve to deceive insects, seeing that they secrete no honey, while in the case of the night-flowers all guides would be useless, since the darkness would render them invisible, and insects in search of honey would be as dependent on their sense of smell and touch as if no markings were present.

(8.) *Form of the Flower.*—The form of the flower, especially that of the corolla, is, in respect of fertilisation by insects, by no means a matter of indifference. Frequently the flower is so constructed as to offer a convenient support to the insects that may have alighted on it while in the act of sucking the honey. If, for example, we glance at the labiate flower copied in Fig. 86, *a*, we shall see at once that the casque-shaped upper lip (*o*) completely covers the anthers and stigma, while the three-cleft lower lip (*u*) is admirably adapted to form a support

on which an insect may rest while penetrating the flower in search of the nectary. We see, therefore, how in this flower the form of the corolla is most intimately connected with the visits of insects. In Fig. 274 we have a similar flower, that of the white dead-nettle (*Lamium album*), and a humble-bee at work in it. Seated on the lower lip, the bee is busy sucking the honey. Fig. 275 shows the position taken by the honey-bee on the flower of the violet while extracting the nectar from the spur. In the twayblade (*Listera ovata*, one of the orchids, Fig. 277) one of the petals is much elongated, and serves as a convenient resting-place for the small beetles (*Grammoptera* among others) which visit the flower. The long curved stamens of the horse-chestnut (*Æsculus Hippocastanum*) are utilised by the humble-bee for a like purpose (Fig. 276).

The form of the flower, however, is modified in connection with other conditions than these. Many plants are so entirely dependent upon insects for fertilisation, that if no insects visit them, fertilisation does not take place at all, self-fertilisation being impossible. Others, again, when the normal insect-fertilisation does not occur, have arrangements whereby self-

FIG. 276.

FIG. 274. FIG. 275. FIG. 277.

Fig. 274.—A humble-bee (*Bombus hortorum*) on the flower of the white dead-nettle. Fig. 275.—Honey-bee (*Apis mellifica*) in the flower of a violet. Fig. 276.—Humble-bee in the flower of horse-chestnut. Fig. 277.—A beetle (*Grammoptera*) on the flower of the twayblade (*Listera ovata*); four times enlarged.

fertilisation is accomplished, so that the production of seed is so far secured, even although it may be inferior in point of size and quality to that of cross-fertilised plants.

In cases where self-fertilisation does not occur under any circumstances, the form or relative position of the various organs of the flower is usually such that anthers and stigma cannot possibly come in contact. The relative position of the floral organs is of course dependent on the whole structure of the flowers in the different species of plants, and no general rules on the subject can be laid down. In a subsequent chapter we shall have something to say of the peculiarities of certain home species in this respect.

Here we may cite in passing a few of the more common peculiarities of insect-fertilised plants, by which, just as in the case of wind-fertilised plants (see p. 171), self-fertilisation is rendered either altogether impossible, or at any rate very difficult. In the plants referred to (see p. 176) self-fertilisation we saw was prevented by their being dicœcious, or if hermaphrodite, by dichogamy. The same peculiarities prevail among the insect-fertilised plants. In some of the latter, however, there is in operation, over and above, a peculiarity which we may term "inequality of styles," or *di-* (*tri-*) *morphism.*

(*a.*) *Dicœcious Flowers.*—The restriction of anthers to one flower and ovaries to another, renders, as already repeatedly stated, cross-fertilisation absolutely necessary.

(*b.*) *Dichogamy.*—The meaning of this term has already been explained (see p. 176). While in the case of wind-fertilised plants protogyny chiefly prevails, in insect-fertilised plants protandry is more common (♂-♀). The anthers, as a rule, develop first, and after they are past the stigma matures.

(*c.*) *Inequality of Styles.*—Inequality of styles is a peculiarity exclusively characteristic of hermaphrodite insect-fertilised plants. Plants possessed of this peculiarity have two or three different forms of flower. Each individual, however, only bears one form of flower. One individual may have one form, another the second, another the third. Each flower contains both stamens and carpels, but the situation of these organs, their size, &c., differs in the different forms.

Many plants possess two different sorts of flowers, and such, therefore, may be designated dimorphic. One of the best known dimorphic plants is the primrose (*Primula vulgaris* and *elatior*). We shall therefore choose it as our first example of inequality of styles (Fig. 278). In I. and III. are re-

presented the two different forms assumed by this flower. These two are distinguished from each other externally, in so far as I. has at the throat, *a* (*entrance to the corolla tube*), a

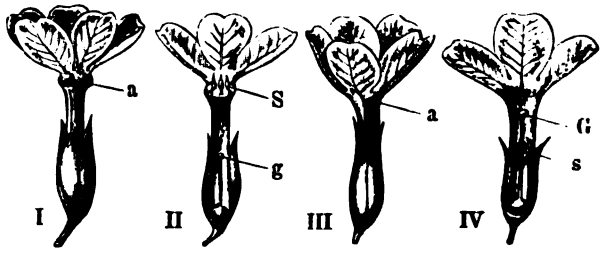


FIG. 278.

Dimorphous flowers of the primrose (*Primula elatior*).—I., II. Short-styled form; III., IV. Long-styled form; nat. size. *a* Throat of the corolla, *S s* Stamens, *G g* Styles.

swelling, and III. at the corresponding point has none. In section, the two flowers are seen to differ internally as follows:— The first flower (II. corresponding to I.) has stamens with very short filaments arranged around the entrance to the corolla tube (*s*). The style in this case is short, the stigma being situated about half-way up the tube. In the second flower (IV. corresponding to III.) the positions of stamens and stigma are reversed. In it the stamens are not at the entrance to the tube, but are placed half-way down (*s*), while the style is double the length of that of II., and the stigma (*s*) is situated almost in the throat of the corolla. The first has a short style, and stamens inserted high up in the corolla tube, the second a long style, and stamens inserted far down in the corolla tube.

The first represents the *short-styled*, the second the *long-styled* form of the primrose. Similar dimorphism is observed in the flowers of the lung-wort (*Pulmonaria officinalis*, Fig. 279). In this plant also we find short-styled and long-styled flowers borne by different individuals. The short-styled flower (I.) has a funnel-shaped corolla tube; at its entrance are attached the five anthers, surmounted by five tufts of hair (*S*, II.). The thread-like style reaches about half-way up the tube (*g*). In the long-styled form (III., IV.) the tube suddenly narrows at its upper end (*a*), being thereafter prolonged downwards in the form of a cylinder. The stamens are inserted about half-way

up, while the style is so long as to project somewhat from the throat of the corolla.

By very exact observations it has been shown that pollen from the stamens of a short-styled flower is powerless to fertilise its own stigma, but is capable of fertilising that of any long-

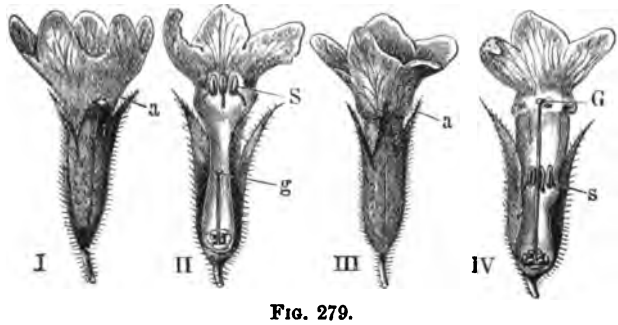
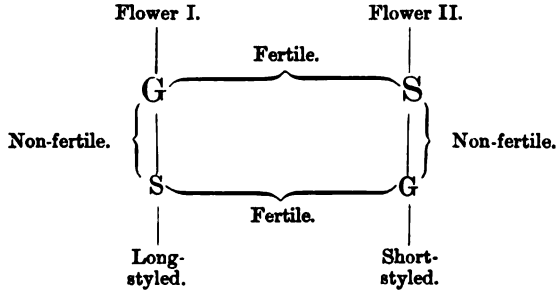


FIG. 279.

Dimorphous flowers of the lung-wort (*Pulmonaria officinalis*).—I., II. Short-styled form; III., IV. Long-styled form; two times enlarged. *a* Throat, *S s* Stamens, *G g* Styles.

styled form. The pollen of long-styled flowers again will only fertilise stigmas of the short-styled form. Taking, therefore, the letters used in Figs. 278 and 279, we may express these relations as follows :—



Neither in primrose nor lung-wort, therefore, can self-fertilisation be effected, even although the pollen may reach the stigma. To such plants cross-fertilisation is absolutely necessary, and is all the more easily secured, that an insect in visiting, say, the short-styled form, brushes against the anthers with a certain part of his body, and carries off with him, when he leaves the flower, a quantity of their pollen. Suppose that next he enters

a long-styled flower, that part of his body on which the pollen is deposited will now brush against the stigma, to which some of the pollen grains brought from the short-styled flower will remain adherent. This arrangement secures cross-fertilisation almost as well as that in which male and female flowers are borne by different individuals. Native dimorphic plants are all species of primrose (*Primula*), the lung-wort (*Pulmonaria officinalis*), the water primrose (*Hottonia palustris*), some flaxes (*Linum*), and the buckwheat (*Polygonum Fagopyrum*).

A still more complicated arrangement for ensuring crossing is that known as trimorphism. In trimorphic plants we find not only two, but three different forms of flowers. One of the best known trimorphic plants is the loosestrife (*Lythrum Salicaria*, Fig. 280), which is frequently found growing in our marshy meadows. Flowers of the first form have a very long style (*G*), five somewhat shorter stamens (stamens of medium length) *S*, and five very short (*s'*) stamens. Flowers of the second form contain five long stamens (*S*), a style of medium length (*g*), and five short stamens (*s'*). The third form has five long stamens (*S*), five stamens of medium length (*s*), and a short style (*g'*). In all these flowers fertilisation only takes place when the pollen of the long stamens (*S*) reaches the stigma of the long style (*G*); or, secondly, when the pollen of the stamens of medium length (*s*) is transferred to the corresponding stigma (*g*); or, thirdly, when the pollen of the short stamens (*s'*) comes into contact with the short style (*g'*). All other crossing, *e.g.*, long style with

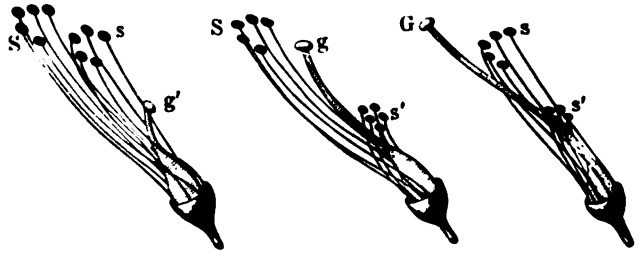
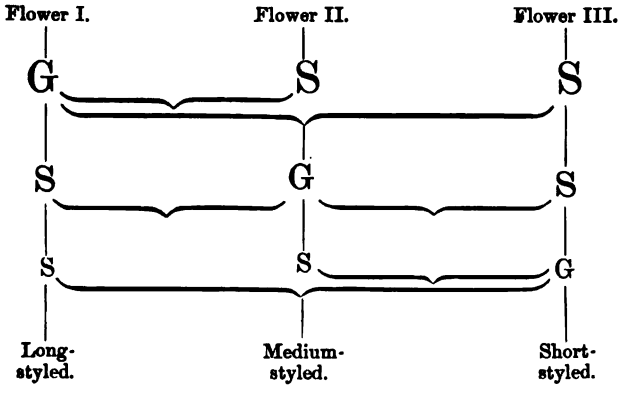


FIG. 280.

Enlarged diagram of stamens and style of loosestrife (*Lythrum Salicaria*) to show trimorphism.

pollen of medium sized and short stamens, medium sized styles with pollen of long and short stamens, short style with pollen of long and medium sized stamens, are respectively unfruitful. If the three lengths of style are represented by *G* (three different sizes), the three lengths of stamens by *S* (different sizes), then all possible crossings

between the three forms having fertilisation as their result, may be expressed by the following plan :—



6.—*Exclusion of Insects whose visits would be injurious.*

Many plants possess contrivances for keeping off from their flowers such insects as might visit them only for the sake of robbing them of the food they supplied, without effecting the transference of the pollen. Such contrivances are highly necessary, as thieves of this kind are by no means uncommon in the insect world.

The pungent, disagreeable smell of many flowers is one excellent adaptation for keeping away enemies, insects being as susceptible as man in this respect. Moreover, foul smells attract such insects as live on putrid flesh, &c., and thus flowers possessing them get a chance of being fertilised, while at the same time acting as a protection to their sweet-smelling neighbours, who would only be injured were carrion flies and the like to find their way to them.

Other flowers repel many insects by their colour. Dark purple-coloured flowers, for example, are usually sought only by the carrion flies referred to above; their colour attracts these creatures, while it is avoided by those which do not live on putrefying matters.

The flowers of many water plants are, from their situation, inaccessible to wingless insects,—the ants, for example. Such are the flowers of the water-lily, water-buttercup, frogbit, &c.

Many peculiarities of structure have also been developed by plants for the purpose of excluding enemies from their flowers. Prickly stems, thorny bracts, and such-like, render it impossible for soft insects to enter the flowers. Sometimes the leaves or stems (catchfly) secrete a viscid fluid, which effectually arrests little animals on their way to the flowers. The protective function is, however, most frequently exercised by modifications of the flower-stalk, calyx, and corolla itself. These may be illustrated by a few examples.

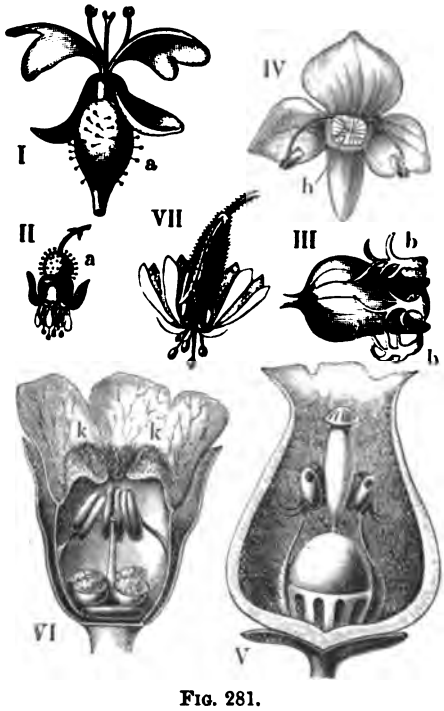


FIG. 281.

I. Flower of the enchanter's nightshade (*Circæa alpina*), five times enlarged. II. Of the gooseberry (*Ribes Grossularia*), nat. size. III. Of *Tellima grandiflora*, twice enlarged. IV. Of speedwell (*Veronica officinalis*), four times enlarged. V. Of the bearberry (*Arctostaphylos Uva-Ursi*), six times enlarged. VI. Of *Cynoglossum pictum*, four times enlarged. VII. Of the nodding campion (*Lychnis nutans*) at midnight, nat. size.—(After Kerner.)

In many plants the calyx or the inferior ovary is coated with a viscid gummy or resinous fluid, which prevents small creeping insects from entering the flower. In general this fluid is secreted by glandular hairs. In Fig. 281, I., we have the flower of the enchanter's nightshade (*Circæa alpina*), the ovary of which bristles with stiff, secreting hairs (*a*). Similar structures are found on the drooping flower of the gooseberry (*Ribes Grossularia*, Fig. 281, II. *a*). These hairs are sometimes replaced by stiff prickles, whose points are directed backwards. These are well-marked in the involucre of the centaury and thistle (Fig. 115, p. 67). In other cases (Fig. 281, III. *b*) the petals are bent back so as to bar the entrance to the interior of the flower. Frequently the sur-

face of the flower is covered by a network of hairs, which prevents many insects from reaching the nectary. Such a network is found on the petals of the speedwell (*Veronica officinalis*, Fig. 281, IV.), the entrance to the throat of the corolla being closed by a ring of stiff bristles. The nectary of the flower of the bearberry (*Arctostaphylus Uva-Ursi*, Fig. 281, V.) is sufficiently well protected by a large number of interlacing hairs, which occupy the interior of the flower. Sometimes special processes are developed, which act as valves, closing the entrance to the nectary. For instance, five of these valves are found in the flower of the hound's-tongue (*Cynoglossum pictum*, Fig. 281, VI.), in which the five hood-like flaps (*k*) form a barrier against the entrance of small insects. Only humble-bees, honey-bees, and other larger insects have strength enough to thrust their proboscis between them. In the nodding campion the arrangements for attracting desirable insects, and for excluding undesirable ones, are both very perfect. Wingless insects are shut out on the one hand by the sticky stems of the plant, and on the other by the glandular hairs of the calyx and peduncle (Fig. 281, VII.). The plant is fertilised by the agency of moths, and therefore its pure white petals only unclose at night, at which time also it gives out a strong, sweet fragrance. The visits of day insects are unwelcome. Accordingly, in the day-time the flower is scentless, and only the dirty green of the under surface of its petals is visible.

2.—*Adaptations in Insects for the Fertilisation of Flowers.*

The following are the chief subdivisions of the Class Insecta: —Coleoptera (Beetles), Diptera (Flies), Hemiptera (Bugs, Aphides, &c.), Hymenoptera (Bees, Wasps, Ants, Sawflies), Lepidoptera (Moths and Butterflies) Neuroptera (Caddis Flies, &c.), Orthoptera (Crickets, Grasshoppers, Cockroaches, &c.).

Of these the Coleoptera, the Lepidoptera, the Diptera, and the Hymenoptera are the orders most concerned in the fertilisation of flowers. More rarely, fertilisation is effected by one or other species of Hemiptera, Neuroptera, and Orthoptera, but these are not of sufficient importance to demand further attention here. We shall therefore confine our remarks to the orders constituting the former group, and consider the various physical peculiarities by which insects belonging to them are enabled to effect the end

in question. Such peculiarities chiefly take the form of *special structures* (invariably confined to the head), *by means of which the insects are enabled to reach and abstract the honey* contained in the flower. We shall also have to consider the *organs concerned in the transport of the pollen.*

(1.) *Lepidoptera* (*Butterflies and Moths*).—The order Lepidoptera comprises many species of great importance in effecting the process of fertilisation. Their large wings are well adapted for rapid flight from flower to flower, and their long proboscis enables them to reach the honey even when the nectary lies at the bottom of a very long and narrow corolla tube.

The position assumed by the butterflies when engaged in abstracting the honey deserves notice. The wings, which during flight flutter to and fro with a rapid motion, are folded together perpendicularly over the body, in which position they are maintained so long as the insect remains poised on the flower (Fig. 282). The butterfly is thus enabled more readily to escape detection by its many enemies (*e.g.*, birds) than if, when resting, its brilliant wings were outspread. The under surface of the wings is usually of a much less striking colour than the upper, and consequently does not prove so attractive. It even happens in many instances that butterflies only visit such flowers as are of the same colour as their own wings, this precaution, of course, rendering detection extremely difficult. Many blue butterflies show a marked preference for blue meadow flowers, while in the Alps the scarlet lilies and many of the orange-coloured Compositæ are visited almost exclusively by butterflies of like hue. The moths, while extracting honey, do not assume a position similar to that of the butterflies, but hover over the flowers, their wings rapidly vibrating meanwhile.

FIG. 282.

A butterfly (*Hipparchia Janira*) at rest on a cluster of flowers; nat. size.

The butterflies are excellent honey-hunters, because, as already said, their proboscis is very highly developed. It arises

from the head midway between the eyes (*a*, Fig. 283), and frequently exceeds the entire body of the insect in length. When not in use, it is kept coiled up like a watch-spring (I. II.), but can be uncoiled at will, and thrust deep down into the nectary of a flower. The proboscis is hollow, and the honey is sucked up by the extreme tip.

In the butterfly the proboscis is the only part of the mouth that is fully developed. In many insects the mouth is very complicated in structure; but in the butterfly a number of the parts are almost entirely suppressed. The *labial palpi* (I., II., III.), however, are usually pretty well marked. They are long and narrow, and are densely covered with hairs. To these hairs the pollen adheres, while the butterfly is engaged in sucking the honey, and by them it is carried to the stigma of the next flower the insect enters.

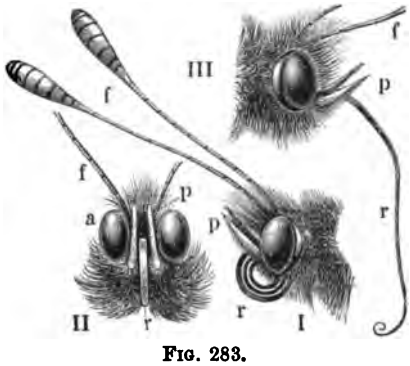


FIG. 283.

Head of *Pieris rapæ* (cabbage butterfly), four times enlarged. I. Side view, showing the proboscis coiled up. II. Front view of the same. III. Side view, showing proboscis uncoiled. *r* Proboscis; *p* Labial palpi; *a* Eyes; *f* Antennæ.

The proboscis is usually from 3 to 7 cm. long, but in many tropical moths it attains a length of over 20 cm. It is by the great length of their proboscis that many butterflies are enabled to suck the honey from flowers having very long and narrow corolla tubes, where it would be quite inaccessible to other insects. We need scarcely say that this feature is a great advantage to the butterfly order, for it means that they have the monopoly of the honey of flowers with a long, tubular corolla. The honey-suckle (*Lonicera Periclymenum*, see Fig. 284) is a good native example of a flower

FIG. 284.

Flower of honeysuckle (*Lonicera Periclymenum*) frequented by privet hawk-moth (*Sphinx ligustri*), nat. size. *a* Nectary; *b* Entrance to the throat of the corolla.

with a tubular corolla, in which the nectary (*a*) is so situated as to be beyond the reach of the various bees and butterflies with short proboscides, likely to be attracted by it in the daytime. In this case the honey is entirely reserved for one of the evening moths (*Sphinx ligustri*) which possess a proboscis of almost exactly the same length as the corolla of the flower—*i.e.*, about 40 mm. Attracted by their fragrance, the insect will hover over a cluster of flowers for a time. Finally selecting one, it uncoils its long proboscis, thrusts it deep into the innermost recesses of the corolla, and, at its leisure, sucks the sweets denied to less fortunate members of its kind.

(2.) *Coleoptera* (*Beetles*).—As fertilisers the beetles are not so important as the butterflies and moths. Only a small proportion pay regular visits to flowers, the greater number deriving their food from quite other sources. Many species which do frequent flowers only effect injury, devouring, as they do, some of their most important organs—*e.g.*, the stamens or the ovary. Others, however, and especially those whose small size admits of their creeping into the interior of the flower, frequently promote cross-fertilisation, the viscid pollen adhering to the general surface of their body, from which it is brushed off by the stigma of the next flower they enter. Such flower-beetles as *Anthrenus*, *Meligethes*, *Malachius*, and certain smaller sorts are extremely useful in this way.

In other species *certain parts of the body* are specially adapted for obtaining food from flowers. Thus, in the crown-beetle (*Cerocoma Schæfferi*, Fig. 285, I., II.), the middle of the antennæ are characterised by very strong and well-defined expansions, and are partly covered with hair. The palpi are very long, and the tongue is provided with two tufts of hair. These form together a large yellow crest on the anterior portion of the head (Fig. 285, II.). In midsummer this beetle is occasionally to be met with on the flower of the milfoil (comp. Fig. 119, *a*, p. 68) and corn marigold. If one of these beetles be caught and examined with a lens, the crest is usually found to be covered with a multitude of little yellow pollen grains.

Among the long-horned beetles the Lepturidæ are specially well-adapted for procuring food from flowers. The anterior part of the body (head and thorax) is narrow and elongated, so as to enable the insect to push its way pretty deeply into the interior

of the flower. The mouth parts are well developed, and stand straight forward from the head. The labium is usually hairy, and is thus extremely useful in extracting honey (Fig. 286, I., II.)[1]

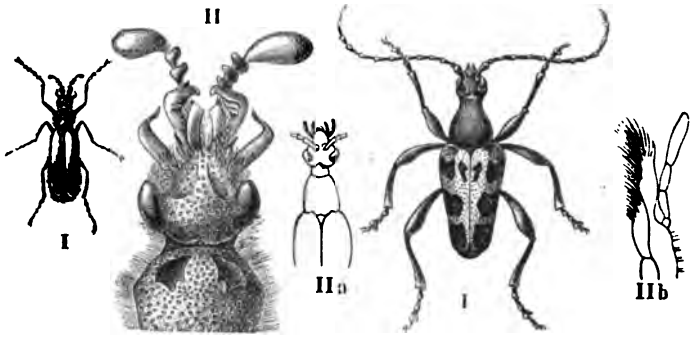


FIG. 285. FIG. 286.

Fig. 286.—Crown beetle (*Cerocoma Schæfferi*).—I. Beetle, nat. size. II. Head, ten times enlarged. Fig. 286.—Longicorn beetles.—I. *Pachyta octomaculata*, three times enlarged. II. *a b Leptura livida*, a head, nat. size, labium. (II. *a b* according to H. Müller.)

(3.) *Diptera* (*Flies*).—Compared with the beetles, Diptera or Flies take a very prominent position as promoters of cross-fertilisation. One great advantage which they have over the former class is their power of free and rapid motion. While the beetles are almost without exception compelled to adopt a slow

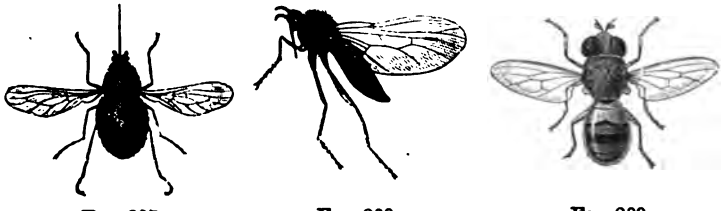


FIG. 287. FIG. 288. FIG. 289.

Fig. 287.—Humble-bee fly (*Bombylius major*), nat. size. Fig. 288.—*Empis livida* (after Meigen), four times enlarged. Fig. 289.—*Syrphus*, nat. size.

mode of locomotion, the movements of the flies are among the most rapid known in the insect world. The number of native species of Diptera is very large; of those which frequent flowers

[1] The rest of the Lepturidæ live for the most part in or on wood. In contrast to the species just described, the thorax is broad, the mouth situated towards the under side of the head, and the maxillæ either very slightly hairy or totally destitute of hairs.

we shall here consider but a few (Figs. 287-291). One of the largest and most rapid flying of the Diptera is the humble-bee fly (*Bombylius major*, Fig. 287). In this species the proboscis, which is situated on the anterior position of the head, is of considerable length, so that the insect can reach the honey even when it is secreted some way down the corolla tube. The manner in which *Bombylius* hovers over a flower while extracting the honey, closely resembles that already described as characteristic of the moths among the Lepidoptera.

The *Empidæ* (Fig. 288) are easily distinguished by the peculiar formation of the head and proboscis. The latter is not directed forwards, but almost perpendicularly downwards, and the head itself is round; the whole thus bearing some resemblance to the long-beaked head of a crane. Many of the *Syrphidæ* are also honey-suckers. In structure they resemble the common house-fly more than the Diptera we have just considered. The posterior part of the body is mostly distinguished by a number of bright and dark coloured bands and specks. As typical examples we may mention the large *Syrphus* (Fig. 289), the allied *Eristalis tenax* and *arbustorum* (Fig. 291), and the cone-fly (*Rhingia rostrata*, Fig. 290). The latter may easily be recognised by its peculiar proboscis, which is kept coiled up under a small conical projection on the anterior part of its head. The sucking apparatus of the Diptera consists of a suctorial proboscis, resembling in a general way that of the common house-fly. It is tubular, short, and thickened at its extremity, so as to form a disk, upon which are furrows and hairs. It is by means of this disk that the honey is taken up. The proboscis of the Diptera being almost always short and blunt, they can only extract honey from such flowers as have an open corolla. Insects of this order, then, need only be sought for on flat flowers, and there indeed they may be seen on any sunny day, rapidly creeping about, and greedily imbibing the nectar. The *Umbelliferæ* (V., Fig. 117, *a*, p. 68) are special favourites with them, the nectar being found on the disk (Fig. 270, IV.) in the centre of the flower, which can very easily be

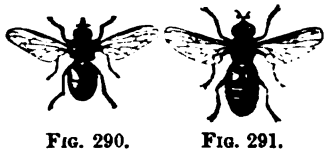


FIG. 290. FIG. 291.

Fig. 290.—Cone-fly (*Rhingia rostrata*), nat. size. Fig. 291.—*Eristalis arbustorum*; nat. style.

reached. The Diptera are never found on flowers with long corolla tubes. Only such forms as the humble-bee flies, *Syrphidæ*, *Empidæ*, and a few others have a proboscis large enough to enable them to obtain honey from flowers of slightly tubular form. The proboscis of *Bombylius* (Fig. 292, I.) is about 1 cm. long. It is strong and stiff, cleft at the extremity (*b*), and thickly beset with hairs. Certain other structures entering into the formation of the mouth (*e.g.*, the lip, *a*, the mandible, *d*, and the maxillæ, *c c*) almost equal it in length. The cone-fly (*Rhingia rostrata*), in common with many other broad-headed flies, possesses the power of coiling up its proboscis, the length of which is about 12 mm. (Fig. 292, II.-IV.). That anterior portion of the cone-fly's head (II.) is prolonged forwards so as to form a sort of beak (*s*). When not in use, the proboscis is kept coiled up beneath this prolongation. When required, the extremity of the proboscis (*b* III.) is first inclined downwards, and the organ is next suddenly shot out to its full length. When fully extended the proboscis projects far beyond the beak-like anterior portion of the head (IV.). The extraction of the honey is effected by means of the cleft tip (*b*). The cleft extremity is used in sucking.

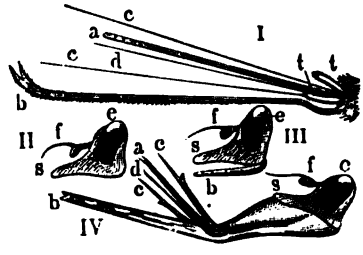


FIG. 292.

Structure of the mouth of the Diptera —I. Humble-bee fly; II.-IV. Cone-fly; II. Side view of head, with the proboscis coiled; III. Do., the proboscis beginning to uncoil; IV. Do., completely uncoiled. *e* Eye, *f* Antennæ, *s* Beak, *t t* Palpi, *b* Extremity of proboscis, *a* Lip, *d* Mandible, *c c* Maxillæ. (II.-IV. after H. Müller).

We have already seen that many flowers are exclusively visited by Lepidoptera, their honey not being within the reach of insects belonging to any other order. Such, for instance, are honeysuckle and privet. Very few flowers, however, are frequented solely by Diptera; for the length of the proboscis, even in those Diptera in which it is best developed, is attained, if not surpassed, by many of the Hymenoptera (humble-bees, honey-bees, &c.). The latter class, therefore, share with the Diptera the privilege of frequenting certain species of flowers. We shall now pass on to consider them for a little.

(4.) *Hymenoptera* (*Bees and Wasps*).—Of all insects the Hymenoptera are, on account both of their physical structure

and their peculiar instincts, the best adapted for the task of extracting and collecting honey from flowers. The species comprised in this order, and more especially the bees, are all characterised by a superior share of intelligence, not only as honey hunters, but in many other respects. Their mode of living together in large, well-ordered communities, presided over by a queen, has long been a subject of marvel and of study. Out of the wax, which exudes at the joints of the abdominal segments of their bodies, they construct a "comb," consisting of a number of united cells. The cells when finished are filled with honey or "bee-bread," a substance composed of a mixture of honey and pollen. This bee-bread forms the food upon which the young larvæ are reared.

The bees are the greatest promoters of cross-fertilisation, not only among the Hymenoptera, but among all insects whatsoever.

Over 200 species of our native bees (*Apidæ*) are known as frequenting flowers, the most familiar being the common honey-bee (Fig. 293). The task of collecting and storing honey is

FIG. 293.

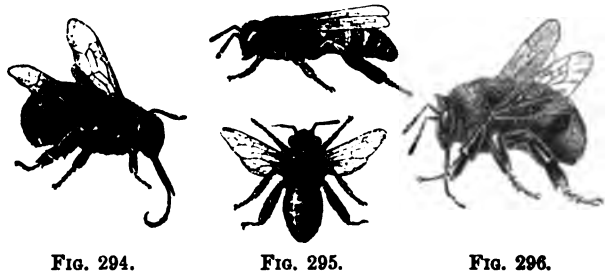


FIG. 294. FIG. 295. FIG. 296.

Hymenoptera.—Fig. 293.—Honey-bee (*Apis mellifica*), Queen; nat. size. Fig. 294.—Hairy-bee (*Anthophora retusa*). Fig. 295.—Earth-bee (*Andrena Schrankella*). Fig. 296.—Humble-bee (*Bombus terrestris*).

performed exclusively by the neuters (workers). The humble-bees do not fall far short of the honey-bees in the assiduity with which they frequent flowers, and they surpass the latter in size and in length of proboscis. Our most common species are the earth humble-bee (*Bombus terrestris*, Fig. 296), the garden humble-bee (*Bombus hortorum*), the moss-bee (*Bombus muscorum*), and the stone-bee (*Bombus lapidarius*). Very similar to the humble-bees in appearance and structure are the hairy-bees, one of which is shown in Fig. 294. They are readily dis-

tinguished, however, as we shall presently see, by the formation of the hind legs. In Fig. 295 we have a sand-bee (*Andrena Schrankella*, a species representing one of the largest genera), which may be seen in early spring on catkins and other spring flowers.

We have already said that, over and above their high intelligence, bees are remarkable for having certain parts of their body specially modified in connection with the acquiring of honey and pollen. We must therefore further consider the structures concerned in effecting this end, viz.—the *suctorial apparatus* and the *apparatus for collecting pollen.*

The suctorial apparatus is in most bees developed in very great perfection. In many (Figs. 294-296) the proboscis is of considerable length, in some cases being as long as the body. It consists (Fig. 297) of the long vermiform tongue (*r*) (as in the butterflies), the upper surface of which is mostly well provided with oblique rows of long bristles. The maxillæ (*k*) and part of the labial palpi (*t*) are modified into flat, leaf-like, linear processes, which are arranged around the tongue (*r*), and thus complete the suctorial proboscis. While, therefore, the suctorial apparatus of the butterfly consists simply of a coiling or suctorial tongue, it must be noted that in the bee other parts are concerned in the formation of the tubular sucking apparatus. In many bees, besides, the tip of the tongue is peculiarly modified, so as to enable the insect to taste the honey before beginning to collect it, an arrangement by which honey of unpleasant taste can be rejected.

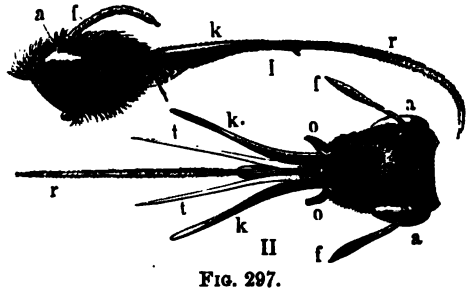


FIG. 297.

Head of *Anthophora retusa*; ten times enlarged. I. Side view; II. Top view. *r* Tongue, *k* Maxillæ, *t* Labial palpi, *o* Mandibles, *t* Antennæ, *a* Eyes.

Apparatus for collecting Pollen.—Of all insects the bees alone have certain parts of their body specialised for the collection of pollen. The structures developed for this end are in their way perfect. They may be found either on the ventral surface of

the posterior portion of the body or on the legs. Accordingly, bees may thus be divided into two groups—(1.) Bees having structures for the collection of pollen on the ventral surface of the body; and (2.) Bees having such structures on their legs. To the first group belong the mason-bees (*Osmia*) and the leaf-cutter bees (*Megachile*). In these species the ventral surface of the abdomen is furnished with long stiff retroverted hairs, by means of which the pollen is brushed from the anthers as the insect passes in or out of the flower. The grains get entangled among the hairs, from among which the bee afterwards dislodges them by means of its legs.

This contrivance is admirably adapted for obtaining pollen from flowers having a flat corolla, but not for such as have the anthers concealed in a deep tube. Our most highly developed bees (humble-bees, honey-bees, &c.) have therefore apparatus suitable for collecting pollen from flowers of all shapes.

The most highly developed bees collect the pollen on the hind legs, but all do not possess the structures adapted to this

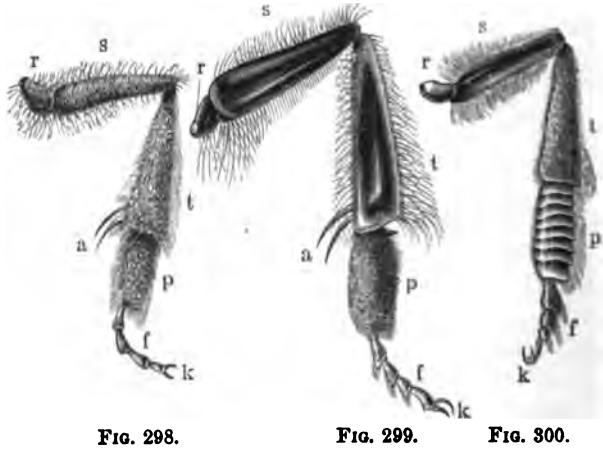


FIG. 298. FIG. 299. FIG. 300.

Hind legs of bees, showing structures for collecting pollen. Fig. 298.—Hairy-bee (*Anthophora retusa*); four times enlarged. Fig. 299.—Humble-bee (*Bombus terrestris*); four times enlarged. Fig. 300.—Honey-bee (*Apis mellifica*, ♀); five times enlarged. *r* Trochanter, *s* Femur, *t* Tibia, *a* Prickles on do., *p* Tarsus (Pollen-brush), *f* Other segments of the foot, *k* Claws.

purpose in like perfection. Fig. 298 represents one of the hind legs of the hairy-bee (*Anthophora retusa*, comp. Fig. 294); we here see the trochanter (*r*), the femur (*s*), the tibia (*t*), the tarsus (*p*), the four other joints of the foot (*f*), and, finally, the two

claws (*k*). The tarsus (*p*) and the tibia (*t*) bear the structures by which the pollen is collected; both are seen to be laden with many grains of pollen (left white in the illustration). The tibia and tarsus are broad and flat, and are thickly covered with hairs. The pollen is brushed from the anthers by means of the hairs on the tarsus (*p*), and is afterwards transferred to those of the tibia (*t*) where they are suffered to remain until the hive is reached. In the humble-bee (Fig. 299, *Bombus terrestris*) the same arrangements are carried out in yet greater perfection. The tibia (*t*) is smooth on the outer surface, while the inner surface is covered with long stiff hairs, which form with the surface of the tibia a little depression, into which the pollen is brushed by the short hairs of the tarsus. In the honey-bee the arrangements are similar to those just described, but the hairs of the tarsus are much better adapted to their purpose (Fig. 300). They are disposed in eight or nine rows, while in the humble-bee they are distributed irregularly. By this regularity

FIG. 301. FIG. 302.

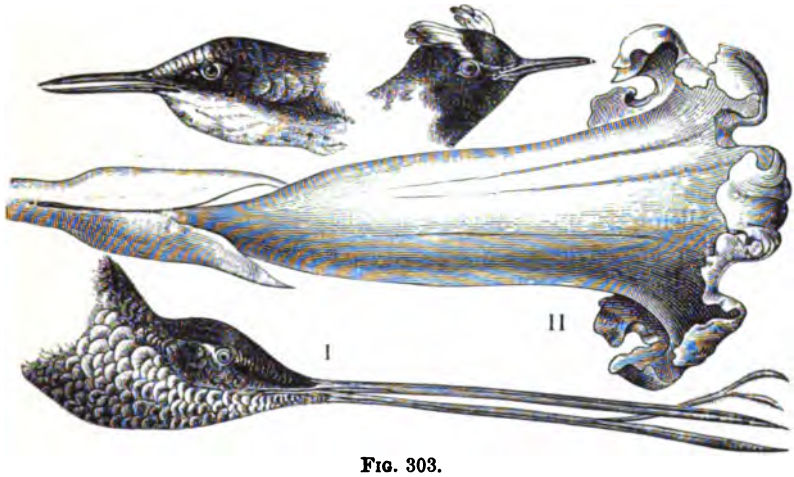


FIG. 303.

Humming-birds.—Fig. 301.—*Heliothrix aurita*; ⅔ nat. size. Fig. 302.—*Heliactinus cornutus*; ⅔ nat. size. Fig. 303.—I. Sword-beak (*Docimastes ensifer*); II. A flower visited by it for its honey (*Datura*); ⅔ nat. size.—(After Brehm.)

of arrangement the honey-bees are enabled to brush the pollen from the anthers far more effectually. The pollen, once removed from the anthers, is next transferred to the hairs, or to the sur-

face of the tibia, to which, being viscid, it readily adheres. After the process of collecting has been carried on for some time, the pollen forms thick yellow masses, which completely envelop the legs. Laden with the fruits of its toil, the insect wings its way homeward, and deposits them in the bee-hive.

(5.) *Birds.*—While our native flowers are many of them entirely dependent on insects for the transference of pollen, the process of cross fertilisation is, in many tropical species, always effected by birds, which visit the flowers on account of their nectar.

In America the humming-birds (*Trochilidæ*, Figs. 301-303), and in Africa the honey-eaters (*Cinnyridæ*) are the great promoters of cross-fertilisation.

The honey-birds are found in the tropical regions of Africa, Asia, and Australia, while the humming-birds belong to Tropical and South America. . The former suck the honey with their long tubular tongue, which is brush-like at the tip. Their relation to flowers has not yet been sufficiently investigated, but a good deal is known respecting those of humming-birds.

The humming-birds are small (the largest species attaining to about the size of a swallow, the smallest not much larger than a humble-bee) and of delicate structure. They are famed for their magnificent plumage, which almost always displays metallic tints. Their flight does not resemble that of any of our native birds, being maintained by rapid vibrations of the wings, which enable them to remain apparently motionless in one spot for a considerable time. Their passage from place to place is effected by a series of rapid darts, almost too swift for the eye to follow. Their flight might perhaps be best compared to that of a moth. Like these insects, the humming-birds hover for long over a flower, sipping the honey with their long, thin bill, and in other particulars also—in colour and form, for example—humming-birds and moths offer some remarkable parallels. Representatives of each may be found, to distinguish between which needs a close scrutiny, and which, when on the wing, might perplex the best observer. To all outward appearance the humming-birds are birds when at rest, insects when in motion.

The tongue of the humming-bird is admirably adapted for extracting the honey from flowers, being really a suctorial tongue

in the truest sense of the expression. Long and tubular, often bifid and hairy at the tip, this organ serves to catch the insects that may be concealed in the flower (Fig. 103, I.). The beak is long, thin, and pointed; the upper jaw closes over the edges of the lower jaw, thus forming a kind of tube encasing the tongue. In almost all species the beak is straight or very slightly curved (Figs. 301-303); in the sicklebeak alone (the *Eutoxeres aquila* of the Equator, for example) it is sickle-shaped. The length of the beak varies in accordance with the length of the corolla tube of the flowers habitually visited by the different species. In the *Heliactinus cornutus* of Brazil (Fig. 302) it is 1·5 cm. long, in the *Heliothrix aurita* of Minas Geraës in Brazil (Fig. 301) about 2 cm. The longest beak among the humming-birds is that of the *Docimastes ensifer* of Venezuela (Fig. 303, I.), that of the female being 8, of the male 10 cm. long. Fig. 303, II., shows a flower of the Datura species frequented by the last-named; we here see how the length of the beak and that of the corolla correspond.

We thus see that in the tropics there are not only wind and insect fertilised flowers, as with us, but also certain which are bird-fertilised, *i.e.*, plants in which the transference of the pollen is effected by humming-birds, &c.

3.—Examples of Insect-Fertilisation.

We shall now speak of the process of fertilisation in certain well-known plants, as serving to illustrate very strikingly the remarkable correspondence between the bodies of insects and the form of many flowers, and further, how entirely dependent on insects many are for the continuance and increase of the species. We have chosen only such flowers as have very perfect arrangements for fertilisation, these being best calculated to demonstrate the points in question.

(1.)—*The Wild Sage* (Salvia pratensis).

The wild sage is pretty common in the sunny meadows of Central Europe. It grows to a height of from $\frac{1}{2}$ to $\frac{3}{4}$ m. The flowers are labiate (p. 123), bright blue in colour, and are arranged in the form of a spike on a long, straight stalk. The lower lip of the corolla is admirably adapted for supporting the

body of an insect while sucking the honey from its nectary (II. Fig. 304). The upper lip is casque-shaped. Its lateral edges

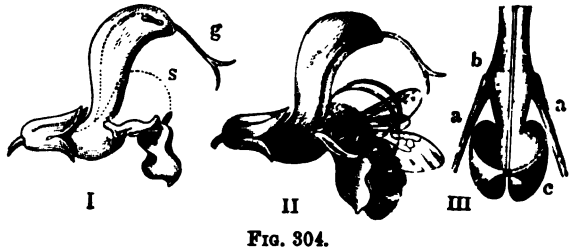


FIG. 304.

Sage (*Salvia pratensis*).—I. Flower from the side; *g* Style; *s* Stamens. II. The same, showing a humble-bee (*Bombus lapidarius*) in the act of extracting the honey, its back at the same time brushing the pollen from the anthers; nat. size. III. Lower part of the stamens enlarged; *a* Processes; *b* Point of union between these and the filament; *c* Spoon-shaped disk.

are so closely approximated that, even when viewed from below the two stamens (I.), its contents can scarcely be seen.

The anthers are thus completely secured against harm from rain. The nectary is situated at the base of the corolla tube, and secretes a large quantity of honey. The stigma is viscid, and is borne on a long style occupying exactly the middle line of the corolla, and projecting for some way beyond it.

Suppose a humble-bee, having just come from a sage-flower, alights upon the one under our consideration. Before entering the corolla his hairy back must needs touch the stigma, depositing thereon some of the pollen brought from the stamens of the flower he has just left. This tribute of pollen must be paid before he can reach the honey he is in quest of. Having settled on the underlip, the bee next proceeds to push its long proboscis downwards towards the nectary, the entrance to which is indicated by a purplish spot. But in the throat of the corolla tube are two longish, narrow processes (*a a*, III.) pointing obliquely outwards: to these the two stamens are attached at the point *b*. Below this point they are attached to a broad spoon-shaped disk, which stretches across the tube and prevents rain from reaching the nectar which lies concealed beneath it. Immediately the disk is touched by the proboscis of the bee, however, it tilts upwards, the two filaments (which are attached to it, and capable of being rotated between the two processes

above-mentioned) being at the same time tilted forwards and downwards. The stamens thus escape from the upper lip, and bend over so that their anthers come into contact with the bee's back, and have some portion of their pollen brushed off by the hairs with which it is covered. In Fig. I. the dotted lines show the stamen before and after (*s*) the disk is raised. In Fig. II. we have a sage blossom showing the anthers in contact with the back of a bee. The bee having extracted all the honey from the nectary, withdraws his head and proboscis, whereupon the disk resumes its former position, and the anthers are drawn up under the upper lip. The bee now leaves this flower, flies to the next, first touches the stigma, there deposits part of the pollen brought with it from the flower it has just left, penetrates the tube with its proboscis, pushes back the stamens, gets covered with pollen, and, in a word, repeats the process above described in every sage flower it visits. This peculiar and ingenious adjustment of parts in the sage, ensures the occurrence always and only of cross-fertilisation by means of the bees.

(2.)—*The Tooth-wort* (Lathræa squamaria).

When in spring-time the woods awake from their long winter sleep, and the dead brown carpet of fallen leaves is bright with many-coloured flowers—

> "When daisies pied, and violets blue,
> And lady-smocks all silver white,
> And cuckoo buds of yellow hue,
> Do paint the meadows with delight"—

a small inconspicuous plant may be found opening its delicate pink buds in the sunshine. The flowers of this plant, the tooth-wort, grow in compact clusters, on a short stalk. Leaves it has none, being a parasite, but the underground stem bears a number of thick yellowish scales, which are modifications of leaves. So pale and delicate it looks, that we feel almost as if it were an intruder among its gay companions. Examined closely, we find that this plant is a great favourite with the humble bees, who find a goodly store of nectar in its blossoms, and achieve its fertilisation in a very remarkable manner.

The formation of the flower of the tooth-wort is as follows (Fig. 305). The large bladder-like calyx (*c*, III.) completely

surrounds the labiate corolla (I.). Both calyx and corolla are of a purple colour, with the exception of the lower lip of the latter, which is of a creamy white towards the tip. The upper and lower lips (*o u*, I.) lie close together, leaving only a small opening in front, so that even in stormy weather all rain is excluded. At the base of the ovary (*k*, VII.) is the glossy yellow, rounded nectary (*n*). The middle of the lower lip is traversed by a longitudinal furrow, corresponding to the nectary. Along this furrow the bee must push his proboscis in order to reach the honey.

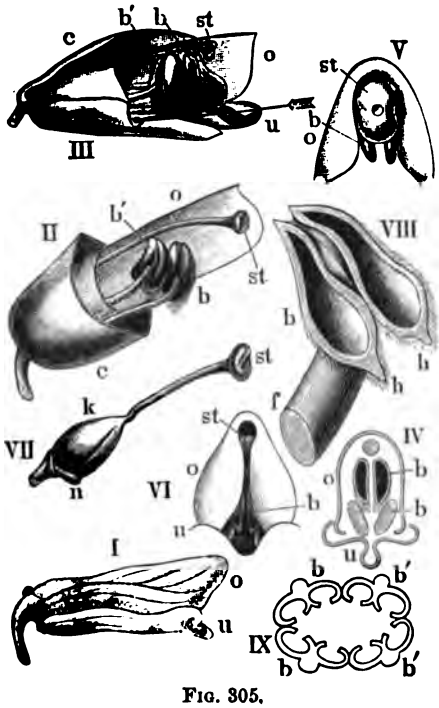


FIG. 305.

Tooth-wort (*Lathræa squamaria*).—I. Flower with calyx removed; II. Flower with ripe stigma (partly in longitudinal section); III. The same, with ripe anthers; IV. Cross-section of flower, viewed from the front; V. Entrance to the corolla (stigma ripe); VI. The same (stamens ripe); VII. Ovary and nectary; VIII. Interior of anther (open); IX. Diagrammatic representation of anthers. I., II., III., VII., two to two and a half times enlarged; VIII. six times enlarged. *c* Calyx; *o* Upper lip of corolla; *u* Lower lip; *s t* Stigma; *k* Ovary; *n* Nectary; *b b'* Anthers; *h* Appendages of the anthers; *f* Filaments. The arrow in III. shows the course of the proboscis of the bee.

The plant is protogynous (p. 176). The knob-like viscid stigma is of a fine reddish purple tint, and occupies the middle of the opening left between the upper and lower lips of the corolla (*s t*, V.). In penetrating the flower with his proboscis the bee must touch the stigma with his head, depositing thereon the pollen brought with him from another flower. Below the stigma (*b b'*, III.) lie the anthers. The insect has to push its proboscis past these, too, but as they are still unripe, it brushes off no pollen.

After the stigma has been fertilised it becomes discoloured and begins to shrink, as does also the style in some degree,

while the upper lip lengthens so as to enclose the stigma (*o*, VI.). The stamens now rapidly increase in length, so as to occupy the entrance to the corolla, the anthers at the same time opening introrsely by longitudinal fissures (VIII.), and shedding the dry dusty pollen. This, however, does not fall down into the flower, but into the space enclosed by the anthers, which lie close together, and have the lower part of their inner surface covered with shaggy hairs. By this arrangement not a single pollen grain is allowed to escape. The base of each stamen is prolonged into a short blunt process (VIII.). If we push a needle slowly along the furrow of the lower lip of the corolla we touch these processes, whereupon the anthers separate and a large quantity of pollen is shed, much as sand is sprinkled from a sand-box. If the needle be withdrawn in time, a small quantity of pollen will be retained by the speedy closing of the anthers.

We are now in a position to understand how the transference of the pollen is effected by the humble-bee. Suppose the insect to visit, in the first place, a flower in which the stamens are ripe: clinging to the flower with its fore legs, it thrusts its head and part of the thorax into the corolla, so as to be able to push its proboscis down into the nectary. The stigma is now in such a position that it cannot be disturbed by the insect, being concealed by the upper lip and anthers, but every motion of the bee's proboscis causes the anthers to spring apart and shed their pollen on the insect's head and thorax. Its task finished, the bee passes to another flower, in which we shall suppose the stigma only is ripe. Upon this, part of the pollen lying on the insect's head is deposited, while he is pushing his proboscis deep into the nectary in search of its hidden sweets. The pollen is enabled to adhere to the stigma by means of the viscidity of the latter.

(3.)—*Fumitory* (Corydalis cava).

In this species of fumitory we have a remarkable example of insect-fertilisation, which differs in certain important respects from the manner in which that process is effected in the two foregoing plants. The flower (Fig. 306, I.) has two small sepals, which drop off early, and are not represented in the accompanying figure, and two large outer petals of peculiar shape (comp. Fig. 247, p. 156). The upper (*a*) is prolonged so as to form a large

spur (*c*), at the lower end of which the nectar is secreted. The lower (*b*) is totally different in shape, and serves as a support for the bee (*Anthophora*) while engaged in sucking honey from the flower. The two outer petals enclose two inner ones (*d* I., II., III.) of peculiar shape. They are united by their tips, and enclose stamens and stigma. The structure so formed we shall designate the *hood*. In the hood we find at *l* (II.) an

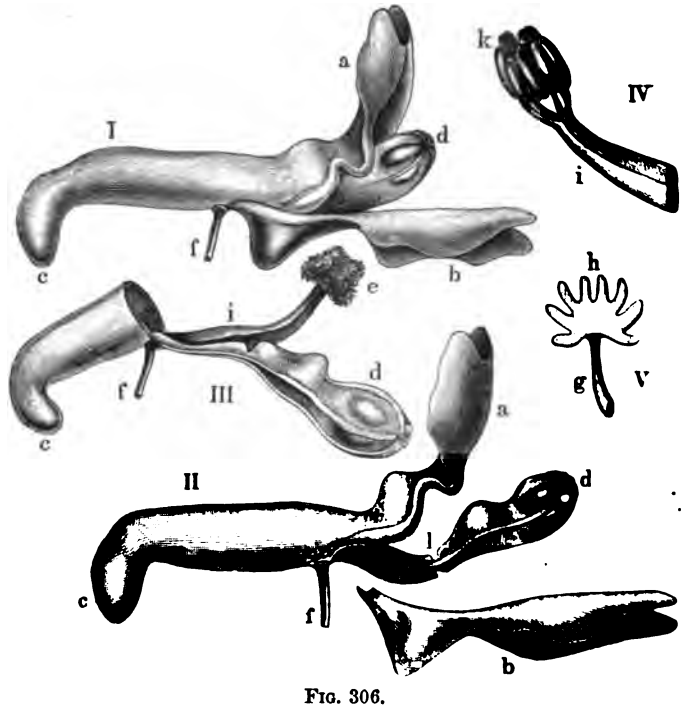


FIG. 306.

Fumitory (*Corydalis cava*).—I. Flower, side view; II. Do., the lower outer petal removed; III. Do., after partial removal of upper outer petal, hood drawn down; IV. Stamens; V. Stigma. (I., II., III. three times enlarged; IV., V. six times enlarged). *a* Upper outer petal, *b* Lower outer petal, *c* Spur, *d* Hood, *l* Joint of hood, *i* Tube formed by filaments, *k* Anthers, *h* Stigma, *g* Style, *e* Stigma with pollen, *f* Peduncle.

indentation above and one below, the upper being the deeper of the two. The hood is thus rendered to a certain degree mobile. If, for example, we touch the hood at the point *d* (I.) it will move in a downward direction, and the stamens and stigma will be liberated (*d c*, III.). The stamens are six in number,

arranged in two bundles of three each (Fig. 247, Fig. 96, III., p. 51). The six filaments form a narrow tube (*i* III., IV.) within which are the ovary and the style. The stigma (*h* V.) lies between the anthers; it is disk-like, and is provided with eight horns. Previous to the opening of the flower the pollen from the anthers is shed upon the stigma while it lies in contact with them. We should, therefore, conclude that here we had a clear case of self-fertilisation. Not so, however. If the flowers of the fumitory are enclosed in a gauze bag, so that all insects are excluded from them, no seed will be produced (comp. p. 169). For the production of seed cross-fertilisation is absolutely necessary, and once again bees are the agents by whose interference it is effected. The insect on reaching the flower pushes its head between the hood and the upper petal, where is the entrance to the nectary. The hood is thus pressed downwards, so that the pollen-laden stigma rubs against the ventral surface of the bee's body, and deposits thereon a quantity of pollen. When the insect leaves the flower, the hood, in virtue of its elasticity, resumes its normal position, and encloses the stigma as before. The bee now passing to another flower, the same process is repeated, but in addition a quantity of pollen from the first flower is deposited on the stigma of the second. In the fumitory we have, therefore, an example of a plant adapted to both self and cross fertilisation, but in which the latter only is effectual in producing seed.

(4.)—*Spotted Orchis and Purple Orchis* (Orchis maculata, O. mascula).

The fertilisation of the orchids is so remarkable, and presents such strange peculiarities, as to render these plants worthy of the closest scrutiny. Let us first of all recall their structure (comp. p. 108). The flowers are arranged in close spikes, and are *irregular* (Fig. 307); the following parts are to be distinguished. On the top of the spirally twisted ovary (*g*) are the three narrow purplish parts (*a b c*) of the outer perianth. These form the upper portion of the flower. Between and within them are two smaller petals (*e f*), very narrow, and cleft at the tip. These are two of the petals proper. The third is directed downwards (*d*); it is much larger, has two lateral appendages, and is conspicu-

ously marked by streaks indicating the position of the nectary (I.). It forms the landing stage upon which insects rest while sucking the honey. The streaks all tend towards the centre of the flower, at which point (*i*) we find the entrance to the nectary, which is situated in the spur (*n*). Immediately over the entrance to the spur is a small club-shaped projection (*s*), to which the stamens and stigma are attached. These are of very peculiar structure, which cannot be made out except with the aid of a good magnifying lens.

FIG. 307.

Spotted orchid (*Orchis maculata*), nat. size. I. Front view; II. Side view. *g* Ovary; *a b c* Outer envelope; *d e f* Corolla; *d* Lower lip; *l* Its lateral appendages; *n* Spur; *i* Entrance to spur; *s* Stamen.

In Fig. 308 we have the stamens and stigma of the spotted orchis (*Orchis maculata*), ten times enlarged. Above is a club-shaped structure (*a* III., IV.), which, when viewed from the front, is seen to be divided into two halves (*a a*, III.). Each half forms a membranous sac, open in front throughout its whole length. The membrane forming the wall of the sac is of a dull purple colour. Under the lens each sac is seen to contain a greenish-grey spheroidal mass, the surface of which is much furrowed. This mass consists of a number of pollen grains, which adhere to one another; each sac is an anther lobe.

The pollen masses (Fig. 308, III., and Fig. 309) are attached to very delicate stalks (*s*, Fig. 309, I., II.), which are attached below to a flat viscid disk (*k*). While the pollen masses are yet in the sacs, the stalk and disk fit into a pouch-like protuberance, indicated by *k* in Fig. 309, III. This cup-like structure is elastic, so as to admit of its being easily pressed downwards. It reverts, however, to its original position when the pressure is withdrawn. The cup or rostellum, as it is called, is the dorsal part of the stigma, and contains the viscid disks to which the stalks of the pollen masses are attached.

The following pretty little experiment may now be made:—Push the point of a very finely sharpened lead pencil into the spur of the flower (*n*, Fig. 308), in the direction indicated by the arrow (I.). The rostellum is thus touched, upon which it moves

back, and the disk (*k*) of the pollen mass comes into contact with the pencil point. When the pencil is withdrawn, the two

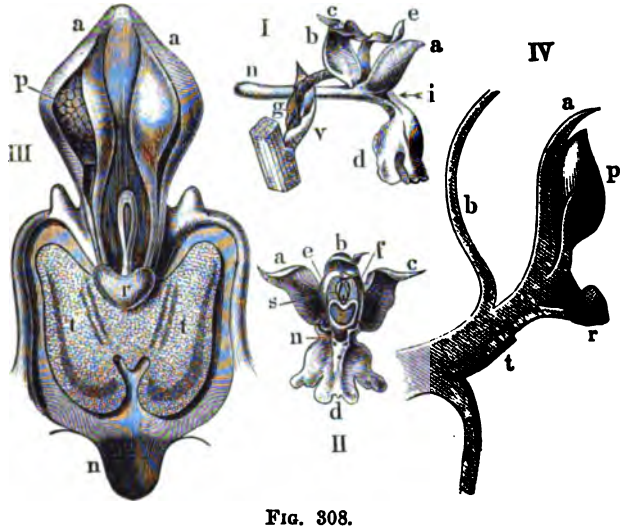


FIG. 308.

Spotted orchis (*Orchis maculata*).—I. Flower, side view. II. Do., front view. III. Stamen and stigma, front view. IV. Do., side view. (I., II., nat. size.; III., IV., ten times enlarged.) I., II. Letters as in Fig. 307, III., IV. *a* Stamen; *p* Pollen mass; *r* Rostellum; *t* Stigma; *n* Entrance to spur; *b* Middle outer perianth petal.

pollen masses will be found adhering to its surface (I., Fig. 309). Held against the light, we see with the lens that the stalks of the pollen masses by-and-by begin to move, so that at length the masses, instead of being perpendicular to the surface of the pencil (I.), are parallel with it (II.). If we now push the point of the pencil (II.) into another flower in the same manner as before, it will be found that the masses are so placed as to come into immediate contact with the spot indicated by the letters *t t* (III., Fig. 308). This spot is the stigma, which is viscid. When the pencil is withdrawn, part of the pollen will be found to have adhered to it.

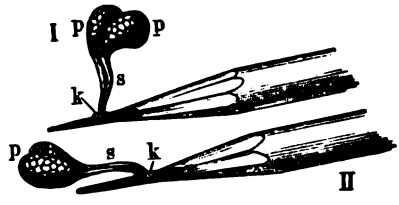


FIG. 309.

Pollen masses of the orchid adhering to pencil points. *p* Pollen masses; *s* Stalk; *k* Disk, six times enlarged.

From this experiment we can easily understand how the process of insect-fertilisation is carried on. The Empis fly (*Empis livida*, Fig. 288) may be taken as a typical fertiliser of these orchids. Attracted by the brilliant colour of a flower, it alights on the broad lower lip, and, guided by the numerous spots and streaks, it thrusts its proboscis into the nectary. In doing so its head knocks against the rostellum, which immediately springs back, and the two pollen masses are clapped on to the insect's eyes. This can scarcely be supposed to be an agreeable surprise for him, but nevertheless he does not let it stand in the way of his enjoyment, but composedly retains his position in the flower until he has extracted all its honey. He then goes to another flower with like intent. Meanwhile, however, the pollen masses have bent over, so that as soon as he enters the corolla they are at once pushed against the stigma. Upon leaving this flower he again carries off its pollen, which is left on a third stigma, and so on. These arrangements, complicated though they are, are yet so exact that cross-fertilisation is effected in almost every case.

(5.)—*Fly-Orchis* (Ophrys muscifera).

The process of insect-fertilisation in the orchids is in every way the most beautiful and interesting we have yet contemplated. It gains yet more in importance from the fact that, besides the two already considered, nearly forty different species of these plants are to be found in Britain. All bear a certain resemblance to each other in structure, but the arrangement of parts differs in each, no two being exactly similar. If we also include foreign species, we shall find that among the orchids alone the arrangements for fertilisation are far more numerous and varied than we could ever have imagined.

The fly-orchis (*Ophrys muscifera*), for example, is fertilised in much the same manner as the species last under consideration, yet there are certain differences to be met with in the details of the arrangements by which fertilisation is effected. In Fig. 310 we have the flower of a fly-orchis, I. showing the front, II. the side view. In general appearance this flower

is said to resemble a fly (whence the name), but it requires some stretch of the imagination to see this.

The lower lip (*labellum, u*) is large, and serves as a landing-stage for insects. It is marked by brownish purple streaks, and has a moist surface. The moisture is licked up by the insects (flies), which, while consuming it, gradually move upwards from the margin to the centre (*t*), where are the two pollen sacs (*a a*, III.). While in the ordinary orchids there is but one rostellum, which forms a cup to contain the stalks of the pollen masses, in the fly-orchid it is bilobed, so that each mass has a cup to itself (*r r*). When the insect pushes back the rostellum and liberates one of the pollen masses, that organ, being inelastic, does not spring back to its old position.

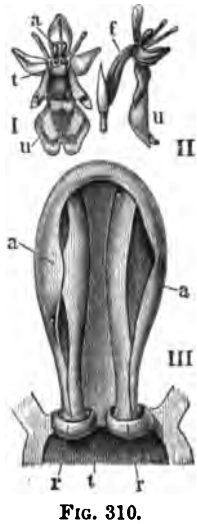


FIG. 310.

Fly-Orchis (*Ophrys muscifera*). — I., II. Flower (nat. size); III. Stamen, ten times enlarged; *f* Ovary; *u s* Lower lip; *a* Pollen sacs; *t* Stigma.

If in the orchids the rostellum were inelastic, one of the pollen masses might be lost (its adhesive disk getting dried up) if the insect were not able to carry off both at once. But, being elastic, the rostellum is enabled to surround the remaining pollen mass, which is accordingly preserved until some other insect carries it away and utilises it for purposes of fertilisation. The elasticity of the rostellum is thus of great advantage to the orchids, but in such a flower as the fly-orchis, where each pollen mass has a separate cup, such a property would be of no use, and, accordingly, has not been developed.

The stalk of the pollen mass of the fly-orchis is S-shaped. About six minutes after the mass has been removed from the sac, this stalk will be found to have assumed a horizontal position. Now six minutes is just about the time an insect takes to get to another flower and finish sipping its store of honey, so that when the insect withdraws its head from the nectary, the pollen mass is ready for transference to the stigma (*t* I., II.). The latter is represented by the broad heart-shaped surface immediately below the rostellum. The insect, in the act of leaving the flower, knocks its head against this surface, on which part of the pollen is thus deposited.

(6.)—*The Butterfly Orchis* (Habenaria bifolia).

As regards fertilisation, the butterfly orchis comes next in order. The perianth (I., Fig. 311) is composed of three broad white outer petals (*o, u, u*), and three narrow, lanceolate inner petals (*v, l*). The lowermost petal is directed downwards, and is known as the tongue. In the centre of the flower (*n*) is the entrance to the nectary, which is of great length, the honey being secreted at the lower extremity. Immediately over the entrance to the nectary are the two pollen sacs (*a*). This species is a night flower, and as such it is characterised by a pale yellow colour and the absence of all markings. The flower diffuses a very strong sweet fragrance, especially by night. Fertilisation is effected by means of nocturnal moths, &c., which have a long proboscis (*Hadena, Plusia, Cucullia, &c.*), for which reason the plant has acquired its inaccurate popular name.

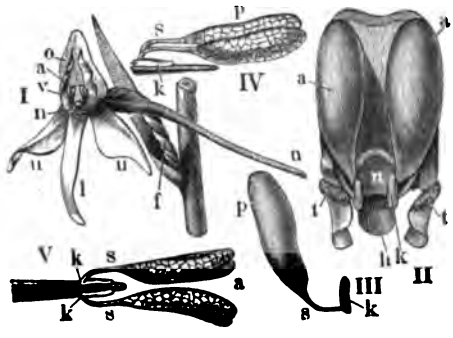


FIG. 311.

Butterfly orchis (*Habenaria bifolia*).—I. Flower, nat. size; II. Pollen sacs, front view; III.-V. Pollen masses in different positions. II.-V. ten times enlarged. *f* Ovary; *n* Spur; *o u u* Outer perianth segments; *v* Upper inner perianth segments; *l* Tongue; *a* Pollen sacs; *h* Entrance to spur; *n* (II.) Stigma; *k* Disk; *s* Pedicels; *p* Pollen masses; *t t* Rudiments of anther.

The structure (II.) of the anther is somewhat different from that of the two orchids already considered. The longitudinal fissure by which each is traversed is not median, but lateral, and cannot be seen when the sacs are viewed from the front. The pollen masses are elongated (*p*, III.), and have a curved stalk. There is no cup containing fluid, but the two viscid disks lie close to the entrance to the spur (*h*, II.; *k* is one of the disks). As the moth sinks his long proboscis into the spur, the disks come into contact with its posterior extremity or with the insect's head (eyes). To one or other of these they adhere, being coated on the under side with a sticky fluid which readily hardens in contact with any foreign body. While the moth is on his way to another flower, the pedicels bend in the same manner as those of other orchids.

Here, however, the bending goes on to such an extent that the anterior portion of the pollen mass is directed downwards and inwards, while its thick end splits asunder. The pollen masses are then in such a position that when the insect passes to another flower they must come in contact with its stigma. The stigma is situated exactly between the adhesive disks over the entrance to the spur (*n*), so that the moth cannot reach the nectary without having some portion of the pollen rubbed by it from its head.

(7.)—*Helleborine* (Cephalanthera pallens).

This orchid differs considerably from those we have hitherto considered. With the latter cross-fertilisation was a necessity, but in Cephalanthera seed is produced as the result both of self and of cross fertilisation.

Fig. 312, I., represents a flower (natural size) as seen from the side. The flower is epigynous. The white petals of the perianth are closely united and curved inwards at the tips, so that the entrance to the corolla is almost tube-like. When the side petals (II. III.) are removed, the narrow labellum, together with a long cylindrical column (*s*), may be seen. (These structures are shown apart in Fig. IV.) The column is directed towards the upper part of the flower: it tapers off suddenly at its upper end, where it supports a large knob, the anther (*a*, IV.-VII.). The anther consists (as in examples 4 to 6) of two elongated sacs (VI., VII.), each of which con-

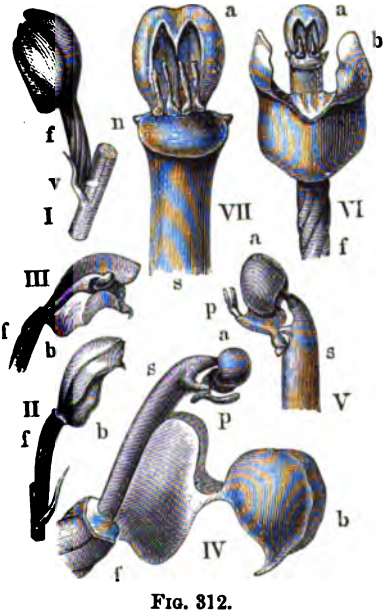


FIG. 312.

Helleborine (*Cephalanthera pallens.*)—I. Flower, side view; II. Do. after removal of the lateral petal; III. Do. longitudinal section; IV. Flower after removal of all the petals with the exception of the labellum, side view; V. Anthers and stigma, side view; VI. Same as IV., stamens and stigma, front view. I.-III. nat. size; IV. VI. two and a half times enlarged; V. three times enlarged; VII. three times enlarged. *f* Ovary; *v* Bract; *b* Labellum; *s* Column; *a* Anthers; *b* Pollen masses; *n* Stigma.

tains a pollen mass. Immediately below this structure is the broad, disk-like stigma. While the flower is yet in the bud, the pollen masses are liberated from the sacs and bend forwards, their lower ends still attached to the inner surface of the sacs (IV., V.). Each mass meanwhile splits into two (VII.), after which pollen tubes (comp. p. 168) are developed, penetrate the stigma, and reach the ovules. Fertilisation is thus effected without transference of pollen from another plant. In addition to this, however, cross-fertilisation is by no means uncommon.

The labellum (*b*, II.-IV., VI.) is of very peculiar shape. It is divided into two halves (*f*, *b*, IV.), between which is a narrow junction. When the flower is open the boat-like anterior portion is bent somewhat downwards (*b*, IV., VI.), so as to form a convenient though narrow entrance to the flower. The labellum has no nectar by which to attract insects, but it is dotted with numerous fleshy protuberances (Fig. VI.) which seemingly answer quite as well. The insects in devouring these come into contact with the anthers, and get dusted over with its granular pollen. On leaving for another flower the pollen is carried with them, and deposited on its stigma, which they cannot but touch as they consume their repast.

Cephalanthera pallens is thus a plant in which self-fertilisation is common, particularly when the flower is not visited by insects. Cross-fertilisation, however, also occurs, and is of importance to the plant, inasmuch as cross-fertilisation is always productive of better seed (comp. p. 168-170).

(8.)—*Birth-wort* (Aristolochia Clematitis).

Of all plants, the birth-wort may be reckoned that in which the arrangements for insect-fertilisation are the most complete (Fig. 313). The yellow flowers are arranged in a whorl round the stem (I.), their colour making them very conspicuous. Moreover, insects are attracted by a peculiar and to us very disagreeable odour. In the long tubular flower (seen Fig. II. in longitudinal section) there are three parts to be distinguished: the wide, funnel-shaped throat (*s*, the entrance to the corolla), the long and narrow tube (*r*), and a lower cauldron-shaped expansion (*k*), which rests on the ovary and encloses the

stigma and stamens. The two last-named parts are united so as to form a fleshy hexagonal body, from whose upper surface arises the stigma, while the six stamens (*a*) are directly united to its sides. The inner surface of the tube is thickly beset with stiff hairs, the points of which are directed downwards. These hairs

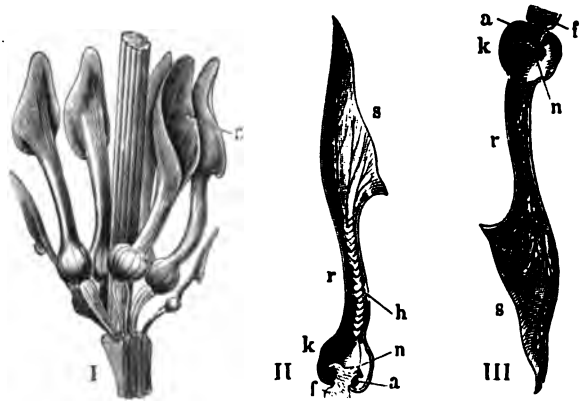


FIG. 313.

Birth-wort (*Aristolochia Clematitis*).—I. Inflorescence, nat. size. II. Transverse sections of flower before fertilisation; III. Do. after fertilisation. Two times enlarged. *s* Throat; *r* Tube; *h* Hair; *k* Cauldron-shaped expansion; *n* Stigma; *a* Anthers; *f* Ovary.

are moveable at their point of articulation with the tube. The inner side is quite covered with thick, stiff hairs, which, however, are readily moveable at the point of attachment (*h*), and the ends of which are directed downwards.

The fertilisation of these plants is effected by small gnat-like insects. These fly into the wide opening of the flower and crawl down the tube, a task of no great difficulty, seeing that the downward direction of the hairs causes them to offer no hindrance to the passage of an insect. Eventually they reach the expansion at the lower end of the tube, which they take possession of as a safe hiding-place. When desirous of leaving the flower, they naturally try to return by the way they came. But now the hairs lining the tube, instead of parting to make way for them, effectually bar all means of egress, and the insects are caught like fish in a net. Running hither and thither in search of some outlet from their prison, they of course cross the large stigma, upon which is deposited the pollen they have brought with them

from some other flower. The stigma of the birth-wort ripens before the anthers, so that this flower is protogynous. Immediately after the stigma has been fertilised, the anthers open (III. *a*), and are emptied by the imprisoned insects in the course of their distracted running to and fro. Meanwhile certain changes take place in the tube. The hairs lining it wither and shrink together, so that the road to the throat of the corolla once more presents no obstacle to the passage of insects (*r*, III.). The peduncle also bends over, so that the flower assumes a somewhat drooping position. The tiny prisoners now make their way outwards as fast as possible, and fly off to another flower, where the above process is again repeated. Once more they are imprisoned, and once more they deposit their burden of pollen on the stigma, only to have it replaced by a fresh supply from the opening anthers. Finally, they once more regain their freedom, but, untaught by experience, speedily lose it in some other flower.

Conclusion.—In the foregoing chapters we have gained some acquaintance with the manifold arrangements by which self-fertilisation is prevented, and cross-fertilisation secured. The importance of the latter process was insisted on from the very outset (see p. 168). We have seen how the almost endless variety in the form of flowers, and in the position and mutual relations of the different organs, can only be explained when we consider their requirements in respect of insect-fertilisation. The first two parts of this work treated of the form of the flower; the third, which treated of the relation between plants and insects, has taught us how that form has come to be what it is. In the first two parts we were concerned with the form of the flower *in general;* in the third, with the form of the flower *in particular*, and with the *causes by which its peculiarities are determined.*

Although, speaking generally, we may say that crossing is the normal mode of fertilisation in many plants, we must not forget that in many others self-fertilisation is equally normal and almost equally successful. Such, for example, is the case with many insect-fertilised plants which are so circumstanced as not to be within reach of frequent and regular visitation. Fertilisation may not then be productive of such great results; but, in any case, self-fertilisation is to be preferred to no fertilisation at

all—imperfect to total fruitlessness. It would, however, appear that even where self-fertilisation is the rule, cross-fertilisation from time to time occurs, the result being invariably improvement of the offspring.

Most plants are dependent on insects for the transference of pollen, these again being dependent on flowers for the means of continued existence. This mutual inter-dependence of insects and flowers—of the animal and the vegetable world—is one of the most surprising and remarkable phenomena in nature.

Transport of Seeds and Fruits.

Having completed our study of the arrangements for cross-fertilisation, and for securing the utmost possible perfection in the nature of the seed, let us now look for a little at the means by which the future welfare of the young plant is provided for, and such advantages as good soil, &c. secured to it.

Dissemination is, as we shall shortly see, of the highest importance to the plant. Suppose that a cherry tree, having had its blossoms fertilised by insects, bears exactly a thousand cherries, each one containing a seed capable of germination. All things being equal, we should thus have, were the cherry seeds sown, a thousand young cherry trees next year. But if the cherries were allowed to ripen on the tree, and, when they dropped off, to sink into the ground immediately beneath the parent plant, it would be impossible for all to germinate. Firstly, a thousand cherry trees could not all flourish in a spot where formerly there was only room for one; and, secondly, the light and air and moisture would all be required by the parent plant, with the result that most, probably all, of the young plants would perish. We therefore find in the fruit of the cherry tree certain arrangements calculated to secure favourable conditions for the development of the young embryo it contains. Its beautiful red colour attracts the notice of many birds, which eagerly devour its juicy pericarp (comp. p. 76). The birds frequently carry the cherries to some quiet nook a long way from the parent tree, there to enjoy them unmolested. The hard kernel containing the seed is of course left intact, and is dropped on the ground. Here the young embryo, as it develops, has a far better chance in the struggle for life and light, than if crowded upon by others of its

own kind. We thus see of what great advantage to a plant is the esculent pericarp of its fruit.

Most fruits and seeds have some special adaptation for securing their transport. The transport of the ripe seeds or fruits is effected by *water, wind, animals,* or by *spontaneous movements* of the seeds themselves.

1.—*Water.*

Water is a very efficient agent in the dispersion of seeds and fruits. Still waters, stagnant pools, ponds, lakes, &c., are of less consequence in this respect than running streams or ocean currents. Of the importance of the latter we have ample evidence when we consider the flora of the banks of some river, rising, say, among the mountains, and then wending their way towards the sea through level plains and grassy meadows. Their lower course is frequently characterised by certain species of mountain plants, whose seeds have been brought down from the uplands by the waters, and cast ashore at some point where they have found conditions favourable to their germination. At the North Cape, the seeds and fruits of various Mexican species have frequently been found borne thither and cast ashore by the waters of the Gulf Stream. In like manner the hard seeds of the "paternoster seed" (*Abrus precatorius*) are washed up on the shores of many tropical countries by ocean currents, and the tree is thus common all along their sea-coasts. The wide range of the cocoa-nut palm (*Cocos nucifera*) is also thus accounted for. Its large nuts, with which we are all familiar, may be carried by ocean currents for hundreds and even thousands of miles, after which, when washed ashore, they are still capable of germinating.

Fruits or seeds dispersed by water have the following distinctive characteristics:—

(1.) They are lighter than water, bulk for bulk, and so are enabled to float on its surface.

(2.) They are impermeable to water, and so do not spoil in course of transport.

(1.) Seeds or fruits which are heavier than water sink to the bottom, and there perish. The fruit of the ivory nut (*Phytelephas macrocarpa*, see p. 113), for example, cannot on this account be transported by water. Some fruits (*e.g.*, those of the water-lily) are enabled to keep afloat by means of large air-spaces which they contain.

(2.) Many seeds are easily damaged by water, and so cannot avail themselves of this means of transport. Those which are transported by water usually have some provision for securing them from the injurious effects of damp. Many (*e.g.*, the fruits of the arrowhead (*Sagittaria sagittifolia*, Fig. 161, II., p. 105) have a smooth, oily rind, which the water cannot penetrate. In others, again, the rind is woody and fibrous (cocoa-nut), and so thick that the water cannot reach the seed. Seeds may remain unharmed in fresh water longer than in salt, the many mineral constituents of the latter enabling it to penetrate more quickly to the contained embryo. Comparatively few plants have as yet been found whose seeds or fruits are capable, like the cocoa-nut, of resisting salt water during an indefinite period.

2.—*Wind.*

Regarded as a means of transport, wind is much better than water, inasmuch as it bears the seeds much more swiftly to their destination. Moreover, while water can only carry the seeds to river banks or sea coasts, wind can bear them to the most inaccessible spots among the mountains, &c. Very lofty mountain chains and broad arms of the sea do, however, usually act as a barrier to the dispersion of seeds,—the former because their summits rise above the height of a particular aërial current, the latter because the seeds gradually sink while being carried across them, and, falling into the water, perish before they reach the opposite side.

Special organs for the conveyance of seed by the wind usually take the form of hairs or feather-like structures, attached either to the fruit as a whole, or to the individual seeds. A broader surface is thus obtained, while the weight is not sensibly increased, and the seed is therefore enabled to remain longer suspended in the air. Sometimes the hairs, &c. are so disposed that the seed on separating from the plant falls with a rotatory motion, by which the wind is enabled to catch it up more readily.

Organs for flight are more commonly found on fruits than on seeds. Some fruits, indeed, owe their popular names to the fact of their being possessed of such organs.

In the bignonia (*Bignonia echinata* of New Granada) the seeds are provided with delicate membranous transparent wings, by which they are kept suspended in the air, while describing large circles, after the manner of a bird of prey.

The winged fruit of the maple is familiar to all (Fig. 125, p. 73). A single fruit, after separating from the plant, rotates slowly downward through the air. The wind thus has an opportunity of catching

it up and bearing it to some distance. The winged nuts of the elm (Fig. 124, p. 73) and the ash have similar arrangements for ensuring dissemination.

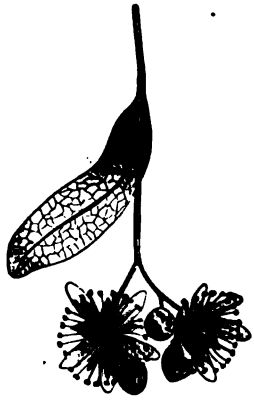


FIG. 314.

Bract of the lime-tree (*Tilia parvifolia*), which serves to support the fruit in the air; position during descent from the tree; nat. size.

In the lime the bract at the base of the inflorescence serves the same purpose as the wings of the maple, &c. After the fruit is ripe the inflorescence drops off and falls to the ground, in the position seen in Fig. 314. While falling, it slowly rotates around the peduncle (main axis).

Downy or hairy appendages are common on seeds and fruits, and form very efficient instruments for their dispersion by the wind. In many plants the seeds are completely covered with long hairs; in others, again, the hairs are arranged in tufts at certain parts. Of these numerous and beautiful arrangements we can here only glance at a few of the more perfect.

The willow is an example of a plant having hairy seeds, the hairs in this case forming a tuft. In the Pasque flower (*Pulsatilla pratensis*, Fig. 315, I.) and the Alpine anemone (*Pulsatilla alpina*, Fig. 315, II.) the style of the ovary remains attached to the fruit. The style is covered with silvery, shining hairs, by which the fruit is enabled to remain suspended in air.

FIG. 315.

Pappus on achenes.—I. Pasque flower (*Pulsatilla pratensis*). II. Alpine anemone (*Pulsatilla alpina*); twice enlarged.

In the Compositæ, the calyx, with few exceptions, is specialised as a means of flight; it forms what is called the *pappus* of the fruit (p. 128), and consists of a number of long, rigid hairs, arranged in a circle at the upper extremity of the achene (p. 73). Each hair is either simple (as in the dandelion) or feathered (as in the *Pennisetum*). Figs. 317 and 318 represent the achenes of two of the Compositæ, surrounded by such a crown of hairs. Fig. 317 is a fruit of the dandelion. Its upper extremity is prolonged so as to form a thin style-like process, far surpassing

the fruit proper in length, and bearing at its tip the delicate pappus, which may here be compared with a parachute. In consequence of this arrangement the achene falls to the ground in the position shown in the figure. The parachute in Fig. 318 (hawkweed, *Hieracium prœaltum*) is of similar construction,

FIG. 316. FIG. 317. FIG. 318. FIG. 319.

Pappus.—Fig. 316.—*Pennisetum.* Fig. 317.—Dandelion (*Taraxacum officinale*). Fig. 318.—Hawkweed (*Hieracium prœaltum*). Fig. 319.—Bulrush (*Typha angustifolia*); about four times enlarged.

only that it rests immediately on the fruit, and is less widely expanded. The bulrush (*Typha angustifolia*, Fig. 319) produces a large number of small, indehiscent fruits. The lower extremity of each is prolonged downwards so as to form a slender, delicate pedicel, from which arise at three or four points a number of silvery hairs. These are arranged in whorls, and support the fruit in the air. The pappus of the Mexican *Pennisetum* (a species of grass) is very remarkable. The stalk of each spikelet is covered with numerous strong hairs, some of which are feathered. These surround the fruit, and enable it to be transported by the wind to great distances.

3.—*Animals.*

In the dispersion of seeds, as in the crossing of flowers, animals play a highly important part. Whereas cross-fertilisation is mainly effected by insects, the dispersion of seeds and fruits is commonly promoted by the agency of larger animals,

such as birds and mammalia. The characteristics of *fruits* designed to be dispersed by animals coincide very closely with those of *flowers* fertilised by insects (p. 178, &c.). They are as follows:—

(1.) They are conspicuously coloured, so as to render them visible at a distance.

(2.) One or other portion is fleshy and succulent, and suitable for food. The fleshy portion is usually the pericarp.

(3.) Their seeds are hard externally, so as to protect the young embryo from harm until it has reached a spot where it may germinate in safety.

(1.) *Colour.*—The colour of edible fruits is usually such as to make them readily distinguishable some way off. This is managed by the development of such tints as may most easily be made out against the green background of foliage—red, black, yellow, white, &c. Most of our native edible fruits are red (of all shades, from deep crimson to pale pink); others are black or bluish-black; a few white or yellow. If the individual fruits are small (*e.g.*, berries), they are made more conspicuous by being aggregated into bunches (compound fruits). Their position is also of importance in this respect, for such as are hidden by leaves cannot possibly attract attention so easily as those which stand out from the surrounding foliage. Some fruits even remain on the parent plant for some time after the disappearance of the leaves, this being their only chance of securing the coveted attentions of birds, &c.

Native plants having red edible fruits are—the barberry (*Berberis vulgaris*), the spindle-tree (*Euonymus europæus*), the strawberry (*Fragaria vesca*), the rose (*Rosa canina*), the hawthorn (*Crataegus Oxyacantha*), the raspberry (*Rubus Idæus*), the rowan (*Pyrus aucuparia*), the currant (*Ribes rubrum*), the dogwood (*Cornus mas*), the elder (*Sambucus racemosa*), the guelder rose (*Viburnum Opulus*), the woodbine or honeysuckle (*Lonicera Periclymenum* and *Lonicera Xylosteum*), the red whortleberry (*Vaccinium Vitis idæa*), the cranberry (*Vaccinium Oxycoccos*), the bearberry (*Arctostaphylos Uva Ursi*), the holly (*Ilex Aquifolium*), the daphne (*Daphne Mezereum*), the arum (*Arum maculatum*), the asparagus (*Asparagus officinalis*), the lily of the valley (*Convallaria majalis*), &c. Blue, bluish-black, or black edible fruits are those of the alder (*Rhamnus cathartica*), the sloe (*Prunus spinosa*), the bramble (*Rubus polymorphus*), the elder (*Sambucus nigra*), the bilberry (*Vaccinium Myrtillus*), the crowberry

(*Empetrum nigrum*), &c. White berries are those of the mistletoe (*Viscum album*), and snowberry (*Symphoricarpus racemosus*); yellow, those of some species of honeysuckle (*Lonicera tartarica*).

In the barberry, the rowan, and the elder we have examples of fruits where a large number are clustered together so as to render them more conspicuous.

The bright scarlet fruits of the barberry hang in loose clusters, while those of the rowan and the elder are arranged more closely, the berries of the rowan being red, those of the elder black. We have already said that fruits can more easily be detected by birds, &c., the fewer leaves they have about them. In early autumn, for example, the thrushes may be seen picking only such elder berries as grow at the extremities of the branches. Not until later in the season, when food is getting scarce and the leaves are falling, do they begin to look for those lying hidden beneath the foliage.

(2.) *Foods.*—The fruits most sought after by animals are those which they can utilise as food. These are almost all *fleshy* fruits, in which some part has developed into a soft, juicy pulp, which constitutes the food in question. The part so developed is generally either the pericarp (p. 71), or the calyx (as in the rose), or the receptacle (as in the strawberry). We thus see that very various parts of the fruit may become succulent, just as we formerly saw that very various parts of the flower may secrete honey. The seed alone cannot be consumed (being frequently very hard), for were it easily destroyed, the continuance of the species would be imperilled.

The seed may be dispersed in two ways. Either the bird flies off with the fruit in its beak, and having consumed the edible parts, drops the seed on the ground, where, if circumstances are favourable, it germinates, or the seed is actually swallowed, and is only sown after having passed through the bird's stomach and intestines. Owing to the hardness of the shell in which it is enclosed it escapes digestion, and passes out of the body in the fæces, which afterwards act as manure to the germinating embryo, and so favour its further development.

(3.) *Protection of the Seed.*—The seed, as already remarked, is protected by the hard woody endocarp or shell. More rarely it is the mesocarp which becomes woody (see p. 71). In any case the woody layer is always hard and thick enough to resist the sharp beak of a bird, or the effect of the digestive juices in the stomach.

It rarely happens that the seed itself is the food sought after by

animals. Even when such is the case, however, dissemination is effected, for animals in storing up the seeds as a provision for the winter occasionally drop them as they carry them off to their nests, and if this happens where the soil is congenial, the embryo is enabled to develop. Thus the squirrels must be very active agents in the dissemination of the hazel, considering the large quantity of its nuts which they store up every autumn.

Fruits of the kind hitherto considered may be conveniently termed *fleshy* fruits. They are all attractive to animals on account of the food they afford.

There remains, however, yet another class of fruits whose seeds are dependent on animals for dispersion. These, on account of certain qualities which we shall presently describe, may be termed *adhesive* fruits. Their external surface is beset with small points, bristles or prickles, by which they are enabled to cling to the fleece or plumage of any animal with which they may come in contact. They are thus frequently carried to great distances, eventually getting brushed off in one way or another, and so placed in a position favourable to germination.

The fruits of the hound's-tongue (*Cynoglossum officinale*, Fig. 320), for example, are covered with little, curved, hook-like

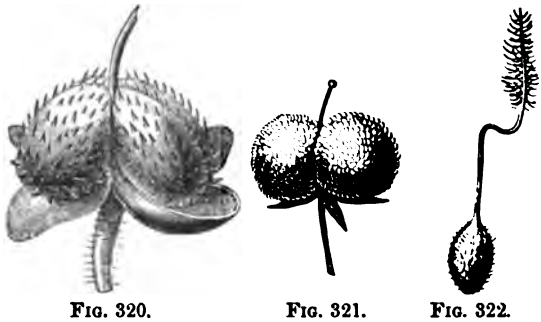


FIG. 320. FIG. 321. FIG. 322.

Adhesive Fruits. **Fig. 320.—Hound's-tongue (*Cynoglossum officinale*). Fig. 321.—Jack-in-the-hedge (*Galium Aparine*). Fig. 322.—Wood-avens (*Geum urbanum*), six times enlarged.**

prickles, which cling very firmly to any rough surface. The surface of the spheroidal fruits of the common "run-the-hedge" (*Galium Aparine*, Fig. 321), is furnished with similar hooked prickles. In the wood-avens (*Geum urbanum*, Fig. 322) the style is persistent, and develops so as to form a strong hook at the summit of the fruit. Every one is familiar, too, with the

burdock. Its bracts are covered with little hooks, by means of which the whole inflorescence (the plant is one of the Compositæ) clings with such firmness to the wool or hair of passing animals, that it can scarcely be got rid of again. On the whole, however, the dispersion of adhesive fruits is more a matter of chance than that of the fleshy fruits, and does not occur so frequently, animals not being dependent on such fruits for food.

While wind and water (more especially the former) are not to be despised as dispersive agents, it is to be noted that animals are unquestionably superior in this respect. Birds, for example, will carry the seeds of a certain species of plant for great distances in perfect safety, whereas, if borne by the wind, they would be dropped on the first obstacle that presented itself, or perhaps fall to the ground only a short distance from the parent plant. The wind, we said, could not carry seeds over lofty mountain chains or wide arms of the sea, but to birds of passage, for example, these form no obstacle. Many inaccessible heights are by their agency covered with verdure. Take the following as an example of their usefulness in this respect. The American currant (*Phytolacca decandra*), an American plant, was long ago introduced into the south of France, and extensively cultivated at Bordeaux, the dark red juice of its berries being used to colour the wines produced in the district. These berries are greedily devoured by certain species of birds, with the result that the plant has now spread over all Southern France and Switzerland, and is now common even in the Tyrol.

4.—*Mode of Dehiscence.*

We have already (see p. 77) had occasion to observe that the pod of the balsam (touch-me-not, *Impatiens noli tangere*), will spring open at the slightest touch, and scatter its seeds to a great distance. Similar phenomena are also seen in other plants. A certain species of cucumber (*Momordica Elaterium*) indigenous to Southern Europe, and more particularly to Greece, has a green prickly fruit about 5 cm. long. When ripe, the slightest touch is sufficient to cause the fruit to spring from its stalk. The seeds are embedded in a quantity of viscid fluid, and when the fruit springs from the stalk, are sent with a gentle whizzing sound to a distance of five or six yards. In many

papilionaceous flowers the valves of the pods as they open curl up, and jerk the seeds to some distance. The three-celled capsule of the violet (Fig. 99, II., p 57), dehisces by three separate valves, each of which is bordered by a row of seeds. The valves as they dry roll together until their edges meet, when the seeds are suddenly scattered far and wide. Many similar instances might be cited, but these are sufficient to show that the movements of the fruit in dehiscing are no unimportant means of dispersion; compared with those previously considered, however, they sink into unimportance. Water, wind, and especially animals, are the great agents concerned in the dispersion of plants over large areas. The "struggle for existence" is thus maintained between species and species on somewhat equal terms, and the chance of extermination in a great degree diminished.

PART IV.

ANATOMY AND PHYSIOLOGY.

INTRODUCTION.

Scope of the Science of Botany.—The sciences dealing with organisms (that is, with animals and plants, see p. 97), viz., Zoology and Botany, pursue in modern times the same method of investigation, and start from the same fundamental principles. The justification of this unity of method and fundamental principle lies in the fact, which must never be lost sight of, that both animal and vegetable structure and function are now known to be based on the same essential phenomena.

When, about two hundred years ago, the study of animals and plants began to be taken up with some degree of earnestness, naturalists first of all directed their efforts to a comparison of the form assumed by similar organs in different organisms, with the result that much variety was found to prevail. It was also found that the same peculiarities were possessed by a number of animals or a number of plants in common, and these common characteristics were used as a means of distinguishing species. Further, known species were arranged together in larger groups, in such a manner that species possessing the greatest number of characteristics in common were placed nearest to each other, those with fewer characteristics in common further away. A classification of plants and animals according to anatomical structure was thus formed, and received the name of *System.*

In the province of Botany, Joseph P. Tournefort, Linnæus, A. L. de Jussieu, and A. P. de Candolle were more particularly concerned in the elaboration of this system; in that of Zoology, Linnæus, Jean Lamarck, and Georges Cuvier. The creator of the modern system was, however, Linnæus, whose works on this subject afford the type on which all subsequent attempts at classification have been formed.

JOSEPH PITTON DE TOURNEFORT was born in 1656 at Aix, in Provence, and from 1683 was Professor at the Jardin des Plantes in Paris, where he died in 1708. His principal work appeared in 1708 under the title "Institutiones Rei Herbariæ" (Principles of Botany).

KARL LINNÈ (usually Latinised as Linnæus) was born in 1707 at Räsbult, in Sweden, was appointed Professor of Botany at the University of Upsala in 1741, and died there in 1778. His writings are extremely numerous, had passed through many editions by the beginning of this century, and up till forty years ago were the sole standard for botanical classification. The great work of Linnæus, in which he unfolded a new system, classifying the three kingdoms of Nature, appeared in 1735 in folio: "Systema Naturæ, sive Regna tria Naturæ systematice proposita" (The System of Nature, or the Three Kingdoms of Nature systematically presented).

ANTOINE LAURENT DE JUSSIEU was born in 1748 at Lyons, and in 1770 was made Professor at the Jardin des Plantes; he died in Paris in 1836. His most important botanical works are "Genera Plantarum secundum ordines naturales disposita," 1789 (Plants grouped according to their Natural Orders), and "Principes de la méthode naturelle des Végétaux," 1824.

AUGUSTIN PYRAME DE CANDOLLE was born in 1778 at Geneva, and died there in 1841. He began the work lately concluded by his son, Alphonse de Candolle, who is still living at Geneva. This work is in seventeen volumes, and is entitled "Prodromus systematis naturalis Regni Vegetabilis," 1824-1873 (Essay towards a Natural System of Classification in Botany). This very important work contains the systematic classification of the dicotyledons (see p. 115), with a precise description of all known species.

JEAN LAMARCK was born in 1744 at Barentin, in Picardy, became Professor of Natural History at the Jardin des Plantes, and died in Paris in 1829, having been blind for a number of years. Of his numerous zoological and botanical works we may mention "Systeme des Animaux sans Vertèbres," 1801, and "Philosophie Zoologique," 1809.

GEORGES CUVIER was born 1769 at Mömpelgard in Würtemberg, removed at an early age to France, and in 1795 was appointed Professor of Zoology in Paris. He was not only a zoologist, but the founder of comparative anatomy. He died in Paris in 1832. His principal work is "Le Règne Animal distribué d'après son organisation."

While attention was thus being directed towards a systematic classification of animals and plants, individual naturalists began to devote themselves to the study of their vital phenomena. In the ancient world the Greek philosopher Aristotle of Stagira had led the way in this department of inquiry, his researches being, however, confined solely to the animal kingdom. Down to the close of the seventeenth century the vital phenomena

of plants had not yet been brought within the scope of human study. It was Marcello Malpighi and Nehemiah Grew who began the investigation of the minute structure of plants, and of their vital processes, their labours being followed up by those of Hales, Ingen-Houss, and especially Théodore de Saussure.

ARISTOTLE, the celebrated Greek philosopher, was born in 384 B.C., at Stagira, and died in 322 B.C., at Chalcis, in Eubœa. Among his numerous writings are many treatises on animal structure and functions, which were much read in the Middle Ages. These remained for long the only works on natural history, no attempt being ever made to improve upon them.

MARCELLO MALPIGHI, born in 1628 at Crevalcuore, near Bologna, was after 1656 Professor at Bologna, Messina, and Pisa. In 1691 he was appointed physician in ordinary to Pope Innocent XII., and died in Rome in 1694. Malpighi was a man of great versatility, being celebrated as a physician, as an anatomist, and as a physiologist. He was the first to write a treatise on the structure of plants—"Anatomia Plantarum" (1675).

NEHEMIAH GREW was born in 1628 at Coventry. He studied medicine, and practised as a physician. In 1677 he was nominated Secretary of the Royal Society of London. He died in 1711. His work on the structure of plants bears the title "The Anatomy of Plants, with an idea of a Philosophical History of Plants" (1672).

STEPHEN HALES was born in 1677 in Kent, and died in 1761. He was at once naturalist and theologian. His principal work on the circulation of sap in plants is entitled "Statical Essays" (1727).

JAN INGEN-HOUSS was born at Breda, in Holland. He became a physician, settled in London, near which city he died in 1799. His great work bears the title "Experiments upon Vegetables, discovering their great power of purifying the common Air in the Sunshine, and of injuring it in the Shade and at Night" (1779).

THEODORE DE SAUSSURE, the most celebrated of the older school of physiological botanists, was born in 1767 at Geneva, where he died in 1845. His great work, "Recherches Chimiques sur la Végétation," appeared in 1804.

Since 1840 the science of the vital phenomena of organisms has been largely developed, and it is now thoroughly recognised that the problems concerned with the phenomena of animal and vegetable life afford one of the greatest fields for the scientific inquiries of the future.

Seeing, however, that the manifold phenomena of life are bound up with individual parts or organs of the body, and are called forth by the operation of one or more of these organs on

others, it follows that exact knowledge of these phenomena can only be the result of careful study of the various parts of the organism. Anatomy, or the science of structure, must precede physiology, or the science of function. These two branches of our subject now fall to be taken up in their order.

The science of botany, as of zoology, is divided into two great parts—

(1.) *Morphology, or science of Form.*
(2.) *Physiology, or science of Function.*

(1.) *Morphology, or the science of form*, embraces in its widest sense all that can be known of the form of any part of an organism. Morphology has to do both with the internal and with the external parts of the body. Strictly speaking, it should begin with the simplest—that is, the smallest—parts, and go on to examine how these are combined so as to form more and more highly complicated organs. In this way it would finally attain to a complete conception of the organism itself. In an elementary text-book, however, there are many difficulties in the way of this course, even though it be the right one. Here it will be advisable to start with the external form, this being much more easily understood than the internal structure. We, therefore, divide the science of morphology into the three following parts:—

(*a.*) External morphology (science of external forms), or science of forms in the narrower sense (organography).
(*b.*) Internal morphology, microscopic anatomy, or histology.
(*c.*) Comparative morphology, including classification.

(*a.*) *External morphology* (organography) has to do with the form of the external and more general characteristics of the plant, treating of the different forms of leaves, flowers, &c., for example. It shows how to form a distinct general idea of what is comprehended under the term leaf, flower, &c., and from that to gain a clear conception of the organism as a whole.

Of the organography of plants, we already know something from Part I.

(*b.*) *Histology, or internal morphology of the organs*, teaches how all the organs treated of by external morphology are composed of a greater or less number of individual parts. Properly, it should proceed from the simple to the complex.

Beginning with the *smallest* recognisable parts of the organism, it acquaints us with the nature of these elementary factors, shows how these fit into each other, and how out of them are built up the most complicated structures. The compotent elements being too small to be perceived by the naked eye, histology in the main has been developed only in modern times, *i.e.*. since microscopes and other appliances have been introduced.[1]

(*c.*) *Comparative Morphology and History of Development.* —General morphology (and anatomy) may investigate any form of animal or plant whatsoever, without regard to the distinctions of species (see p. 97). Comparative morphology (including comparative anatomy) deals with the same organs in a whole series of different animals or plants. It has to do not only with the form and texture of that organ, but also with its position in or on the body, and with the number of smaller parts concerned in its structure. It must thus give some account of how the same organ varies in structure in different organisms. Accordingly it is enabled to separate the essentially like from the essentially unlike, series being thus obtained, the extremes of which, though apparently widely different from each other, are yet bound together by an unbroken chain of intermediate forms.

In many cases, however, it is not enough to compare the *actual* organ in different beings, but it is necessary to study it in all stages of its *growth* and *development*. This latter is the special province of *embryology*, which is an important and indispensable branch of comparative morphology. Among other things, it brings to light many important points of resemblance, which the fully developed organ fails to show.

By the methods here given, comparative morphology finally arrives at the *comprehensive* conception of an organ of whatever kind, a conception distinguished from that of pure (not comparative) morphology, inasmuch as it is to be regarded as an *inference* drawn from a series of observations. The corresponding conception of pure morphology, on the other hand, is obtained from a single observation.

If, for example, we describe with the utmost precision all the organs of any plant whatsoever, we have only succeeded in solving a problem

[1] The compound microscope was invented at the end of the sixteenth century by Hans and Zacharias Janssen, two opticians of Middelburg, in Holland; it was essentially improved in the first half of this century by Amici (1827); also by Hugo von Mohl (1846) and others.

in pure morphology. If, however, we compare even in the roughest manner the different kinds of stem to be met with in various plants, and thus get a comprehensive notion of what is meant by the term axis (pp. 8-15), we have entered upon the field of comparative morphology, and have pursued a more scientific mode of inquiry than in our former study. A truly scientific treatment of morphology and anatomy is possible only by the comparative method.

There are two points from which comparative morphology may view the organs of a given animal or plant.

(1.) According to their structure, position, and development, organs which agree in these points (which are morphologically comparable) are said to be *homologous.*

(2.) According to their function in the living organisms, all organisms which are capable of being compared in respect of their functions (which are physiologically comparable) are said to be *analogous.*

Equivalent or homologous organs are often very dissimilar in the external form, which they assume in different organisms. In all cases, however, the minute structure and the position is the same.

The fore legs of mammalia, the wings of birds, and the fins of fishes are homologous or equivalent organs, all of which are included under the general term fore limbs. Their outward form, which is modified according to the respective functions they have to discharge in particular cases, is very different in different animals. The structure, however, is the same in all. All the three organs above mentioned, for example, contain corresponding bones, and their position, both to each other and in relation to the vertebral column, is the same in every case. So in plants, hairs and prickles (pp. 79-81) are homologous organs, though very different in their external form.

Similar or analogous organs for the most part resemble one another in outward form. They may, however, differ widely in structure and position in different organisms.

The wings of birds and the wings of insects are similar or analogous, and therefore in respect of function comparable, organs. Both are used as organs of flight, and accordingly have a similar outward form. When, however, we come to consider their anatomical structure and their position, we find that there is no comparison between them. Stem and leaf tendrils (see Figs. 19 and 48, p. 14 and 31) are analogous organs; both are used in climbing, and are externally of very similar form. We know, however, that the former belong to the stem, the latter to the leaf. Organs at once both equivalent and similar are, for example, the wings of bats and the wings of birds.

In common language analogous parts have mostly the same name, while homologous parts have frequently different names.

For comparative morphology, the structure of the organs, their position, &c. (that is, their equivalence or homology) is the main matter. From this point of view, function and the external form conditioned by it (that is, similarity or analogy) is a subordinate consideration. Comparative morphology arranges the organs according to homology, not according to analogy.

In Part I. we therefore distinguished the organs of the plant into root, stem, leaf, and hair structures, including, under the head of stem-structures, for example, stem-tendrils (p. 14), under that of leaf-structures, leaf-tendrils (p. 31)—by no means ranking the two side by side as organs for climbing (comp. also thorn and prickles, pp. 79-81).

If we compare all the homologous organs in the bodies of known organisms, we shall find many possessed by a number of species *in common*, and agreeing in structure to a greater or less extent. Organisms having many homologous organs of similar structure are said to be *related*. The degree of relationship is in accordance with the number and agreement of the homologous parts. System (p. 96) consists in the arrangement of animals and plants according to the relationship existing between them. System is based on the results of comparative morphology (and on the history of development), and is the outcome of the study of homologous parts in different species.

A corollary deducible from this proposition is that that system alone is valid, or is a *natural system*, which takes account of all the structural peculiarities of organisms, both in their *actual* and in their *embryonic* or developing state. All systems based one-sidedly on isolated structural peculiarities are to be rejected as artificial; equally clear is it that in general analogies are not to be depended on in the formation of a system. It would be an entire mistake, for example, to class whales with fishes, as Aristotle has done, because of their fins, or to divide plants into trees, shrubs, and herbs after the manner of Tournefort and most of his predecessors.

(2.) *Physiology, or the science of function*, in its widest sense comprehends all studies directed to the knowledge of organic life. By the term *life*, we mean the sum of all expressions or phenomena of life, that is, all the processes which, standing in

intimate connection with each other, tend to the *preservation of the organism*. The sudden cessation of all manifestations of life is called death, and its immediate consequence is the dissolution of the organised parts of the body into non-organised chemical combinations (gases), under the influence of the oxygen of the atmosphere (putrefaction, slow combustion). The origin and ultimate cause of all vital phenomena are physical and chemical processes (molecular movements). The factors proper in the vital processes are the elementary or ultimate constituents of all the tissues of the body. Physiology must therefore start with the study of the vital phenomena in these elementary constituents, viz., the cells, and thence pass to the investigation of the more complicated processes, in which a large number of cells co-operate.

Physiology may also investigate the function of each organ as a whole, omitting the study of the ultimate parts. It does not restrict itself, however, simply to the discovery of the functions of a given organ, but likewise considers the influence exercised by the surrounding media on the development of that organ. Of this branch of physiology,[1] we already know something from the foregoing section; it seeks to explain the functional import and origin of morphological characters.

Physiology, or the science of vital function, is based partly on physics and chemistry, partly on morphology and anatomy. Its facts are tested by experiment. By experiment we are enabled to modify the natural conditions by which a given function is produced, and thereby to bring about some variation or abnormality in that function. In this way we may increase at will the number of possible observations, and thus we are enabled to distinguish between the essential and the non-essential, the normal and the abnormal. The first condition of all correct knowledge of any vital function is, that the experiments conducted with a view to its investigation be arranged in a full and logical series, and carried out without error. The physiological botany of modern times is entirely founded on experiment, a method of investigation introduced mainly by Théodore de Saussure, and elaborated chiefly by Nägeli and Sachs.

[1] Physiology literally means the *nature of growth* (Greek, *physis* and *logos*). Another branch of physiology is psychology (*psyche*), or the science of nervous action. This department, however, lies quite outside the sphere of botany.

In his work already referred to (p. 235), Théodore de Saussure dealt mainly with the processes of alimentation and respiration, and was the first to give a complete and pertinent series of experiments.

JULIUS VON SACHS, born 1832, at Breslau, now Professor of Botany at Würzburg, experimented on the chemical changes which take place in seeds during germination, on the growth of the root and the stem (the mechanics of growth), on the influence exercised on growth by light and heat, &c. His principal works are—"Handbuch des Experimentalphysiologie der Pflanzen," 1866 (Manual of Experimental Physiology of Plants), "Lehrbuch der Botanik," 1874 (Text-Book of Botany, Eng. Trans., 2d Ed., 1884); and "Vorlesungen Ueb. Pflanzen-Physiologie" (Lectures on Vegetable Physiology).

While we divide morphology into pure and comparative morphology, a corresponding division of physiology is as yet impossible. At present we have only *pure* physiology; the elaboration of *comparative* physiology lies mainly in the future. The physiological botanists of these days find that the problems of the former science afford ample scope for their best thought and effort; and, indeed, when we come to consider the youth of the study, we cannot wonder that it has not yet developed a comparative branch. Not a little has been done towards this even already, however, both by observation and experiment (see pp. 162-232).

I.—THE CELL.

1.—MEANING OF THE TERM "CELL."

If we cut across the stem of a herbaceous plant, *e.g.*, the cucumber, we find that on pressing it gently a quantity of fluid—the *sap*—oozes out. The stem is thus not of the same consistence throughout (is not homogeneous), but is composed of solid and fluid constituents; its *structure* is peculiar. Suppose we now cut from the stem in question as thin a slice as possible, and hold it up, between two glass plates, to the light, we then see, with the naked eye, and still more distinctly with a lens, that it consists of a net-like tissue, somewhat resembling thin gauze or tulle.

The appearance of the stem in longitudinal section is similar. With a sufficiently powerful lens we can see that each mesh of tissue contains a small quantity of turbid fluid. This is what is popularly called the sap.

The stem, like every other part of the plant, consists of an enormous number of minute vesicles or "cells," ranged side by side. Each of these is enclosed on all sides by a delicate membrane, and is filled with a somewhat tenacious slimy substance. Every tissue of the plant consists of a very large number of minute (microscopic) cells.

The name cell (Latin *cella*, dim. *cellula*, a chamber or cell) was applied because a section of tissue composed of these cells bears some resemblance to a honey-comb.

So much by way of introduction: let us now consider the characteristics of the cell in general. These may be well studied in many plant hairs, which consist of a single row of cells, and are easily prepared for the microscope. All that is needed is to cut the hair from the plant with a pen-knife, put it in a drop of water between two glass plates, and it is ready for inspection. We shall here examine the delicate hairs which cover the surface of the stamens of Tradescantia (*Tradescantia virginica*). In this example the structure of the cells (Fig. 323) is easily recognised. Each cell is elliptical in shape (I.), and is

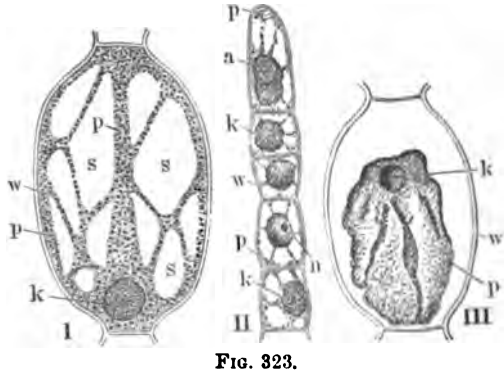


FIG. 323.

Cells from the staminal hairs of *Tradescantia virginica*.—I. Full-grown cell; II. End cells of a very young hair; III. Old cell after being treated with alcohol. *w* Cell-wall, *p* Protoplasm, *s* Cell-sap cavities, *k* Nucleus, *n* Nucleus in act of division; 600 times enlarged.

attached above and below to other single cells. It is surrounded by a very delicate colourless membrane, the *cell-wall* (*w*), which under the microscope (in "optical section") shows as a double line, enclosing a space. The space enclosed by the cell-wall is for

the most part filled with a somewhat turbid, viscid, semi-fluid mass (*p*), through which are scattered granules of various sizes; this is called the plasma or *protoplasm.*[1] Protoplasm is not a solid substance, but a kind of fluid. In the example under consideration it is readily distinguished by its peculiar streaming movement, which is well seen under the microscope. Somewhere near the cell-wall is found a thickish, spheroidal mass, the *nucleus* (*k*). It is soft and plastic, as we shall shortly see. It occupies, especially in young cells (II.), a large portion of the interior (*k*). Within it a darker spot—the *nucleolus* (II., *n*) —is frequently to be distinguished. Besides protoplasm and a nucleus, the cell contains a number of spaces of different size (*s*). These are termed *vacuoles*, and are filled with clear watery fluid. They are separated from each other by bands of protoplasm (I., II.). The watery fluid contained in the vacuoles may be extracted by means of strong alcohol, sulphuric acid, or glycerine. Figure III. represents a cell similar to I., which has been steeped some seconds in absolute alcohol; the watery fluid is in great part withdrawn, and the protoplasm (*p*) has in consequence contracted, so as to form an irregular, sac-like structure enclosing the nucleus (*k*), while the cell-wall (*w*) has become very distinct. Protoplasm, cell-contents, and nucleus are the usual contents of the cell. Besides these there are often, in certain sorts of cells, other solid contents, granules, crystals, &c. These will be considered later on. In the meantime let us proceed to a more minute examination of the constant cell-contents.

Our present way of regarding the substance of the vegetable cell was established at the end of the first half of this century, chiefly by Hugo von Mohl. H. v. Mohl was born in 1805 at Stuttgart, and died in 1872 at Tübingen. Of his numerous writings, those of importance, as bearing on the cell, are "Grundzüge zur Anatomie u. Physiologie der vegetabilischen Zelle," 1851 (Principles for the Anatomy and Physiology of the Vegetable Cell), and "Vermischte Schriften botanischen Inhalts," 1845 (Miscellaneous Essays on Botany).

2.—The Cell-Wall.

Until recently it was supposed that the cell-wall was to be found in connection with all cells. It is, however, now known that in some cases the cell-wall is absent. Thus the

[1] From the Greek *plasma*, something formed; *protos*, first. Protoplasma = first formed matter.

lowest of all living organisms, the Amœba, consists simply of a mass of protoplasm, which moves freely in water, unenclosed by any external membrane.

We must, nevertheless, regard this body as a cell, seeing it has all the essential properties of such. It absorbs water from the outside, and by this means forms vacuoles in its interior. It commonly possesses a nucleus, and it multiplies by division after the manner of other cells.

Even in higher plants, cells consisting simply of a minute protoplasmic mass, unenclosed by a membrane, are occasionally found in very young organs. To distinguish them from those enclosed by a wall, they are called naked cells. We thus see that the cell-wall is by no means essential to the conception of the cell. The analogy between the vegetable cell and a closed cell or chamber is accordingly apt to be misleading.

Where, as is usually the case, the cell is enclosed by a membrane, the latter always owes its origin to the protoplasm. It is developed while the cell is yet in a very early stage of its existence,—while, in fact, it is being formed by division of an antecedent cell. During the first stages of development the cell-wall consists of a very delicate transparent membrane, composed of a peculiar substance termed *cellulose*. This membrane is permeable to water and other fluids, though not possessing any definite openings by which these can pass through. By this property of the cell-wall fluids are enabled to pass from one cell to another, although the membrane surrounds each in unbroken continuity (comp. p. 245).

Cellulose ($C_6H_{10}O_5$) is an organic substance consisting of carbon, hydrogen, and oxygen, and is classed among the group of carbohydrates. Certain sorts of paper—filter paper, for example—consist of almost pure cellulose.

That a membrane of cellulose is permeable to certain fluids, may be demonstrated by the following experiment (Fig. 324) :— Over one end of a cylinder (*a*), about 15 cm. in length and 2 cm. in diameter, stretch a piece of moistened parchment paper, which is almost pure cellulose. An artificial cell is thus formed, which must be filled up to the point *c* with a saturated solution of sulphate of copper. By means of the apparatus shown in Fig. 324, the cylinder is then suspended in a vessel of water (*b*) in such a way that the level of the fluid inside the cylinder shall correspond with the level of the fluid on the outside at the point *c*. After a few days, the fluid in the cylinder will be found to have risen to *d*, while both it and the water contained in the vessel outside will be light blue in colour. While

the experiment has been going on, the following changes have taken place :—Part of the water from *b* has passed through the membrane *f* into *a*, whereby the level has risen to *d*. At the same time a sufficient quantity of the blue sulphate of copper has passed through *f* into *b*, sufficient to render the solutions in *a* and *b* of equal strength. There has thus been diffusion on the part of both fluids. From *a* to *b* the fluid has passed by the process known as exosmosis,—from *b* to *a* by that known as endosmosis. Examination will show that the membrane *f* is still without any visible opening. Cellulose appears primarily as a delicate layer of single granules, which afterwards coalesce so as to form a continuous but permeable membrane.

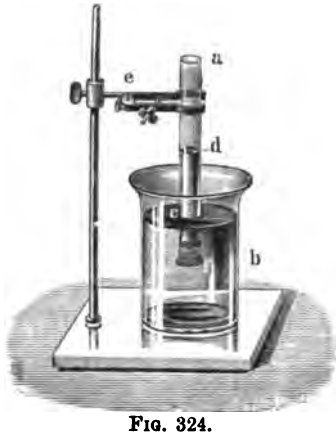


FIG. 324.

The cellulose membrane forming the cell-wall is always originally thin, elastic, and highly ductile. At a later stage of its existence it possesses the property of growth. It then increases in volume—in length, breadth, and thickness—and at the same time undergoes a series of physical and chemical changes. As the cell-wall increases in volume (especially in thickness) its shape becomes more definite, and tends to remain more constant, while the chemical and physical changes which it undergoes later on are calculated to fit it for the performance of the special function which it has to discharge in the organism of which it forms a part.

The membrane, having attained a sufficient degree of thickness and closeness of texture, forms the perfect *cell-wall*.

(1.) *Mode of Growth.*—The process of growth takes place in the cell-wall by the secretion of minute particles (molecules) of protoplasm, which separate from the general mass forming the cell-contents, and attach themselves to the enveloping membrane. This constitutes the process of growth by *intussusception*. If the deposition of new molecules takes place in a horizontal direction, the result is increase of surface ; if the deposition takes place in a perpendicular direction, the result is increase of thickness. This refers to the membrane as a membrane, without regard to the shape it may assume in a particular cell.

If the cell-wall were absolutely homogeneous, such a deposition of new molecules as that above described could hardly take place. On the hitherto generally accepted theory of Nägeli the minute structure of the cell-wall is as follows:—The ultimate molecules of cellulose are conceived of as small spheroidal granules surrounded on all sides by water. The molecules lie above and beside one another, so that in any small portion of membrane we have solid matter and water regularly alternating. If the space between two molecules of cellulose is greater in diameter than the molecules themselves, it will be possible for a minute particle of new matter, if segregated from the general mass, to intercalate itself between these two molecules of cellulose. If such molecular intercalation is of frequent occurrence, we have perceptible increase in the size of the membrane or *growth*. It thus follows that the process of growth does not take place by simple *accretion*, as was formerly supposed, but by intercalation of new molecules among others already existing, *i.e.*, by *intussusception*.[1] Growth is the consequence of this diffusion of certain constituents of protoplasm throughout the cell-membrane.

(2.) *Thickening, Lignification, Cuticularisation.*—A cell-wall may increase in thickness without undergoing any chemical change. The fully developed cell-wall may still consist of cellulose. This is what is meant by *thickening* of the cell-wall. It may be general or local, *i.e.*, while some parts increase in thickness others do not, or the thickening process may stop sooner at one point than at another.

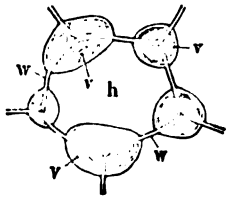


FIG. 325.

Collenchyma cell from the stem of *Richardia africana*. — *w* Unthickened cell-wall; *v* Thickenings of cell-wall; *h* Interior of cell,—600 times enlarged.

In the cells of *collenchyma* we find an example of such partial thickening. The cells of collenchyma are similar to the cells of *parenchyma* (see below), but have their walls thickened where they are attached to other cells. In Fig. 325 we have a collenchyma cell from the stem of the well-known lily of the Nile (*Richardia africana*). In transverse section the cell is seen to be pentagonal; it is united with the other cells in such a manner that every three cell-walls meet in one point. At this point we find a thickening similar to

[1] (See, however, for an essential revival of the older theory, "Strasburger Ueb. d. Bau u. d. Wachsthum d. Zellhäute:" Jena 1882.—Tr.)

these marked *v v* in the figure. This is produced by the concurrence of the three cells, and runs parallel to the long axis of each. The intermediate portions of the cell-wall (*w w*) are not thickened. The characteristic appearance of the collenchyma cell is due to these irregularities in the thickness of its wall.

The process of thickening is usually accompanied by physical and chemical changes in the cell-wall which cause it to assume new properties. In some cases it acquires a high degree of elasticity, and in others it loses its permeability, &c. The two most important modes of thickening, accompanied by chemical change, are lignification and cuticularisation.

Lignification of the cell-wall takes place as follows:—The cell-wall, increasing in thickness by intussusception, becomes differentiated into two, afterwards into three layers. First the place of the primary membrane (p. 245) is taken by the so-called *middle lamella* (*l*, Fig. 326), from which is by-and-by differentiated a second layer (*s*) on the inner surface. Both of these are chemically different from the primary cell-wall. By-and-by there develops between the middle lamella and the inner layer a third layer (*w*), which usually surpasses the other two both in thickness and in strength of texture. The third layer consists of woody substance or *lignin*, which resembles cellulose, but is by no means identical with it. These three laminæ are easily recognised in many cells (comp. 328, p. 252, and Fig. 329, p. 253). The third or middle layer usually appears to be made up of a large number of concentric laminæ. By lignification the cell becomes much harder, and more capable of resisting external influences, at the expense, however, of a great deal of its original elasticity. The protoplasm cannot penetrate the thickened parts of the lignified cell-wall, which nevertheless are freely permeable by water.

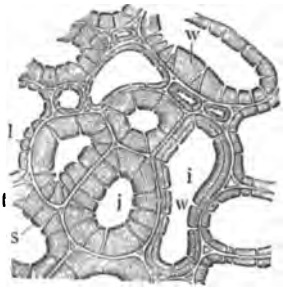


FIG. 326.

Lignified cells from the epicarp (see p. 71) of an unripe walnut (*Juglans regia*); 600 times enlarged. *i* Interior of cell, *l* Middle lamella, *w* The third layer, consisting of woody substance, *s* Inner layer, *t* Pit.

The lamination of the middle layer is due to the unequal distribution of the water it contains. A lighter layer alternates regularly with a darker one. The lighter layers are more watery than the other,

that is, their molecules are separated from each other by larger aqueous envelopes. The darker layers again are less watery, *i.e.*, they have the molecules, of which they are composed, arranged more closely together, so that there is not so much room for water in the interstices.

The process of *cuticularisation* of the cell-wall is similar to that of lignification. In this case, likewise, the thickening cell-wall is subjected to peculiar changes, being converted into cork or *suberin*. It is thus rendered highly elastic, impermeable to water and air, and occurring, as it does, on or close under the surface of vegetable organs, serves as a protective layer against injurious external influences, such as damp and cold. Later we shall examine more thoroughly the two most important forms of cuticularised cell layers.

(3.) *Deposition of Mineral Constituents in the Cell-Wall.*—Occasionally certain mineral matters are found deposited in the cell-wall, changing its appearance more or less. These depositions consist either of calcium carbonate or of silex, the latter being frequently found in large quantities. In many cell-walls the silex is disposed so as to form a regular network, which renders the surface rough to the touch. The silex may also be deposited in the form of crystals.

This is the case with grasses having sharp-edged leaves, for example. In these prominent crystals of silica are found in the cells of the epidermis. The epidermic cells of the horsetails (*Equisetaceæ*) are also highly impregnated with siliceous matter. As the silex resists the action both of acid and of heat, the siliceous skeleton of a leaf may easily be obtained by treating specimens (leaves of grasses, horsetails, &c.), with sulphuric acid, and subjecting to strong heat on a plate of platinum, or simply by boiling them in strong nitric acid. By this means every particle of organic substance will be destroyed, and a complete skeleton of the tissue will remain, formed entirely of silex. Diatoms are similarly prepared.

Besides these comparatively rare mineral substances, which may be directly observed under the microscope, there are in every cell-membrane small particles of various minerals of such minuteness as to baffle the most powerful lenses. As, however, they are not liable to be affected by heat, they may be got at by burning the cell-walls. After leaves have been subjected to this process, the mineral constituents will be found in the shape of a fine white powder, the so-called "ash" of the leaf. When we consider the infinitesimal quantity of ash obtained by burning

a piece of the best Swedish filtering paper (which consists entirely of cellulose), we get an idea of the smallness of the per-centage of mineral matter to be met with in vegetable tissues.

3.—Forms of Cells.

A. *Shape as determined by Surface Growth.*

The shape of the cell is determined by the form assumed by the enclosing membrane,—that is, the change of shape which the cell undergoes in the course of its existence is determined by the manner in which the membrane is forced to grow, especially increasing either in length or breadth.

The form of cells is always at first tolerably regular, spheroidal, cubical, &c., that is to say, the cell is developed pretty equally in all three directions. Later on, however, it in most cases becomes polygonal, as the result of the mutual pressure exerted by the cells in a given tissue during the process of growth. As this pressure is not usually exerted equally in all directions, the shape of the cells is rendered irregular. Cells are most commonly spheroidal, elliptical, or cylindrical, or they may assume the form of four, five, six, or many sided prisms, cones, tetrahedrons, and various parallelopipeds, or again they may be disk-shaped, star-shaped, or multipolar.

Microscopic sections, as a rule, only show us one aspect of a cell. In order, therefore, to become acquainted with the shape of a cell as a whole, it is necessary to examine it, not only in transverse, but also in radial and tangential section. Spheroidal, elliptical, and cylindrical cells all show in transverse section a circular form, and it is not until we have examined each in longitudinal section also that we become acquainted with its true shape.

From what has been already said, it is evident that the shape of each individual cell will depend entirely on the nature of its environment during the process of growth. On the whole, the shape of the cells forming a particular tissue is of subordinate importance. A much more important feature, and one, too, which, as we shall presently see, is of no little consequence from a functional point of view, is the division of cells into parenchyma and prosenchyma. By *parenchyma* cells are meant all

cells which are pretty equally developed in all three directions. Their walls are for the most part, but not always, very thin (see farther under Parenchyma, p. 277).

By *prosenchyma* cells are meant such as are specially developed in a longitudinal direction, while comparatively undeveloped as regards breadth and thickness. Such cells are usually very slender, and pointed at the ends, so as to look somewhat spindle-shaped. Their walls are frequently, but not always, firm in consistence. Prosenchyma cells are never found in the younger and more delicate parts of a plant, which are composed entirely of parenchyma cells. Only as the organ grows older is prosenchyma developed from parenchyma, by processes yet to be described.

Besides the cell forms already mentioned, which, on the whole, are simple, there occur in the lowest plants (in the Algæ, for example) cells of very peculiar shape. Many of these plants consist of *a single cell*. This, however, is frequently branched after the manner of higher plants, with root, stem, and leaves.

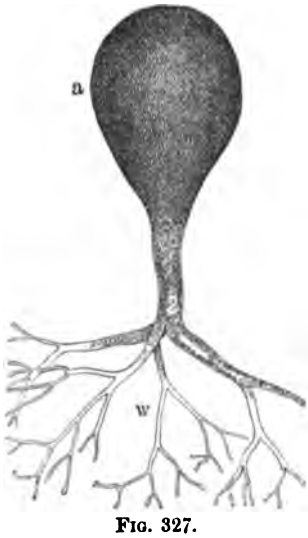


FIG. 327.

A unicellular Alga (*Botrydium granulatum*), fifteen times enlarged. *a* Part above the soil (head); *w* Part under the soil (root).

Fig. 327 represents a unicellular alga (*Botrydium granulatum*), occasionally found on the clayey soil of dried-up swamps and pools. It consists of a a thick balloon-like head (*a*), which is supported on a slender stem, and is of a beautiful green colour. Below, the stem branches so as to form a kind of root (*w*), by which the plant is firmly fixed in the ground. Here, then, is one cell imitating, so to speak, the structure of a higher multicellular plant. This resemblance is still more striking in *Caulerpa* and *Bryopsis*, two genera of Algæ largely represented in European seas. Like *Botrydium*, these are unicellular; the filamentous part of the cell forms a horizontal stem, which, at intervals, sends out tufts of root-like processes in a downward direction, and so-called "fronds" in an upward direction. The "fronds" are lobed or pinnate, and consist of prolongations of the cell-wall and contents flattened out at their upper extremities, so as to resemble the blade of an ordinary leaf.

B. *Shape as determined by increase in Thickness.*

(1.) *Pits.*—Increase in the thickness of the cell-membrane never takes place uniformly at all parts. In many cases the process of thickening is arrested at an early stage of growth, the points at which this has occurred being marked throughout the after existence of the cell by small circular spots. These, as the neighbouring parts of the membrane go on increasing in thickness, are transformed into small tubular canals, which radiate throughout the cell-wall (*t*, Fig. 326). The small, round, membranous spot is termed a *pit;* or if the surrounding parts are much thickened, so as to render it tube-like, a *canal.* These canals form a means of communication between the interior of the cell and the periphery. The pits in neighbouring cell-walls always correspond, as do likewise the canals: so that between every two cells we have one or more of these corresponding depressions. Each pair of these is at first separated by a delicate membrane (the middle lamella) stretched transversely between them; but, later on, this membrane disappears, and free communication between adjoining cells is thus established.

It sometimes happens that in much thickened or lignified walls two canals unite, and so have a common opening into the lumen of the cell. We thus have what is termed a *branched canal.*

Branched canals may be well seen in the thickened parenchyma cells of the walnut (Fig. 326). Still better examples occur in the cells of the woody inner pericarp of the same fruit when nearly ripe, in the bast-cells of the dahlia-tuber, &c.

The number of pits in a cell is very variable. In some cases they are few in number; in others they are so numerous that the cell when viewed from above seems to be entirely dotted over with them, while the thickened parts form a delicate lattice work between. In cross section the pits are usually round, elliptical, or polygonal (four to eight sided); in rare cases they are long, narrow, and elongated at both ends, so as nearly to resemble slits.

A very peculiar form is seen in the wood-cells of the Coniferæ, where we have what are termed *bordered pits.* If a longitudinal section is made through the young shoot of a conifer, like the common yew (*Taxus baccata,* Fig. 328), the following peculiar

structure will be observed. Each individual cell (I., Fig. 328) forms a long cylindrical tube, the wall of which is pretty strong, besides being thickened internally (*s*), after a fashion to be described later on. The surface of the cell is studded with a number of lenticular protuberances (*a*, *a'*), the centre of which is marked by a round or slit-like depression—the pit. In trans-

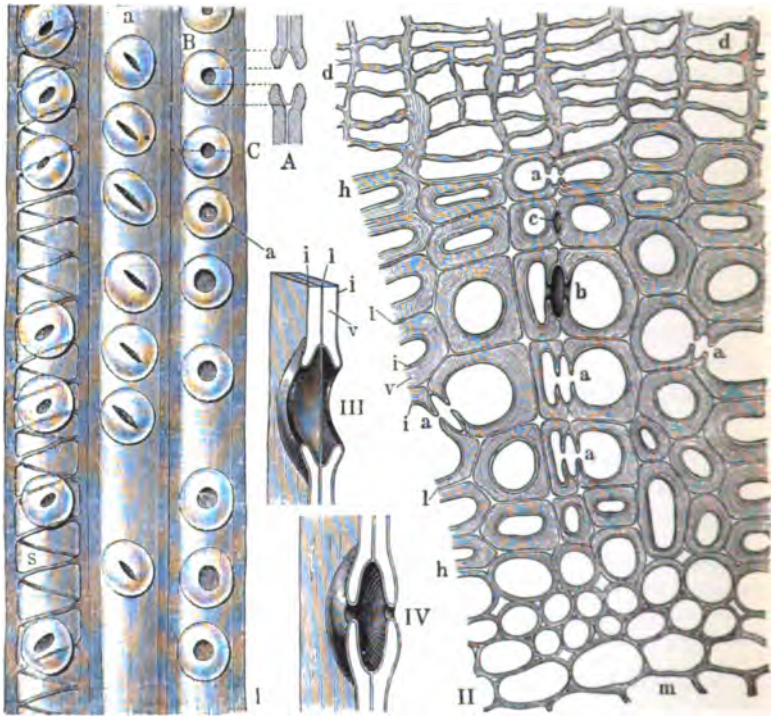


FIG. 328.

Pitted cells of a one-year-old stem of the yew (*Taxus baccata*).—I. Three wood cells in longitudinal section; 1000 times enlarged. *a* Bordered pits with circular opening; *a'* Do. with slit-like opening. *A* Diagrammatic representation of pit *B* in longitudinal section. II. Piece of the same stem in transverse section; 1000 times enlarged. *h h* Wood cells, *m* Pith, *l* Middle lamella, *v* Middle lamina, *i* Inner lamina, *a a* Bordered pits cut across their longest diameter, *b* Do. showing underlying space, *c* Do., transverse section below the middle. III. Diagrammatic representation of a young pit. IV. Do. of an older pit; letters same as in II.

verse section, cutting across a pit at the point *C*, we see that the pit is situated between two adjacent cells (*a*, II.). It forms a narrow elliptical space, the walls of which are pierced on either

side by a small opening.—(See diagrammatic representation, *A*, *B*, Fig. 328, I.). The interior corresponds to the larger circle of the pit in I., while the openings are represented by the smaller circle (*e*). At the point *b* (II.) we have a pit from a part of the section where it is so thick as to show that half of the space which lies below the point of section. The pit *c*, again, has been cut across below the centre, so that the openings into the interior are not seen.

All the pits shown in II. are open,—that is, the middle lamella or membrane, stretching across the lumen of the tube, has disappeared, so that free communication is established between the cells. In the young cells of conifers the middle lamella (p. 247) is always found, and only disappears with age. In Fig. 328, III., we have a diagrammatic representation of a young pitted cell, *l* being the middle lamella; IV. shows the same cell at a later stage, the middle lamella having now disappeared.

(2.) *Partial thickening of the Cell-Wall.*—Although the walls of many cells uniformly increase in thickness, except at such small spots as are afterwards to develop into pits, there are others in which this does not take place, the thickening process being localised in certain larger or smaller areas. As the result of this the full-grown cell frequently assumes a very peculiar appearance.

It sometimes happens, for example, that cells are lignified only on one side, the other remaining unthickened. Of this there are numerous examples in certain cells of the rhizome of many monocotyledons, *e.g.*, those of the lily of the valley (*Convallaria majalis*), shown in Fig. 329. The cell layers denoted by *c* and *d* are composed of slightly thickened parenchyma cells. Between them are two layers consisting of cells (*a*, *b*), the walls of which are conspicuously

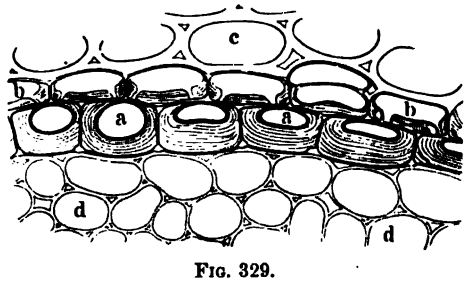


FIG. 329.

Cells (*a*, *b*) from the rhizome of the lily of the valley (*Convallaria majalis*), in transverse section. *d*, *d*, *e* Parenchyma cells; 900 times enlarged.

lignified on the side next the centre of the rhizome. The sides of the cells in the layer *b* are traversed by large wide pits.

Another example of partial thickening is seen in the case of collenchyma cells, already mentioned (p. 246).

The most varied forms of partial thickening occur, however, in those cells which are united to form vascular tissue. Vessels are long and cylindrical in shape, and their walls are not themselves much altered in texture, but are thickened by means of spiral, annular, or reticulated deposits laid down on their inner

FIG. 330.

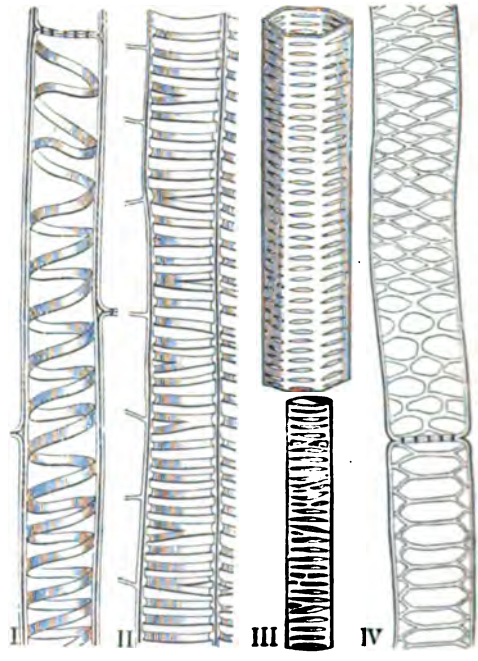


FIG. 331.

Fig. 330.—Diagrammatic representation of a spiral vessel. Fig. 331.—Vessels. I. Young spiral vessel from stem of a seedling plant of *Vicia Faba*; II. Annular vessel from the wood of *Morus alba*; III. Scalariform vessels from the trunk of *Nephrolepis exaltata* (fern); IV. Young reticulated vessels from one of the older roots of a seedling of *Vicia Faba*; about 600 times enlarged. (I., III., IV. General appearance; II. Longitudinal section.)

surface. In Fig. 330 we have a diagrammatic representation of this mode of thickening. The perpendicular cylinder, here perfectly transparent, represents part of a long tubular vessel, the

walls of which are composed of the middle lamella very slightly thickened throughout. The partial thickening, effected by means of a spiral deposit on the inner surface of this membrane, is represented by the spiral band, shaded dark, which in the figure is shown in transverse section at two points, and is seen to be quadrangular. It projects from the general surface a little way into the lumen of the tube.

According to the form assumed by these deposits, vessels are distinguished as follows:—

(*a.*) *Spiral Vessels* (Fig. 331, I.).—In these the deposit forms a continuous spiral. The spiral either runs throughout in one direction, *e.g.*, from right to left, or it suddenly bends back and forms an angle whereby the coils are reversed, and runs from left to right. The turns of the spiral may either be quite close, or more or less distant.

(*b.*) *Annular Vessels.* — In these the deposits are not continuous, but are in separate rings on the interior of the cells, and sometimes incline towards the axis of the vessel (Fig. 331, II.). Annular and spiral vessels are frequently so far commingled that each of the rings just described is connected with the one following it by a short spiral.

(*c.*) *Scalariform Vessels.*—Here the secondary deposits take the form of short bands arranged perpendicularly to the axis of the vessel, occupying only a portion of its inner surface (Fig. 331, III.). These bands are placed so close together, that when viewed in conjunction with the unthickened parts, the latter look like so many horizontal slits in the wall of the vessel.

(*d.*) *Reticulated Vessels.*—In these vessels scalariform ridges are connected by means of short, vertical bars, so as to give the cell-wall the appearance of being covered by an irregular network (Fig. 331, IV.).

(*e.*) *Pitted Vessels.*—These have their walls pretty regularly thickened up to the points at which the pits (simple or bordered) occur. Their structure has already been considered (Fig. 328).

4.—Cell-Contents, Cell-Sap, Protoplasm, and Nucleus.

Generally speaking, the cell may be said to have *fluid contents*, although strictly the term *fluid* cannot be applied to all. We

have already seen (p. 243) that the cell-contents are not homogeneous, but, under normal conditions, are made up of three different substances, the characteristic properties and relations of which must now be considered.

A. *Cell-Sap.*

Irregularly distributed through the contents of each cell are a number of transparent spaces (see Fig. 323, p. 242), the cell-sap cavities or *vacuoles*. These are filled with a clear, transparent fluid, the *cell-sap*. Cell-sap consists mainly of water, which contains, first, mineral matters in solution absorbed by the plant from the soil by means of its roots; and, secondly, various organic combinations formed within the organism as the result of its life.

A certain quantity of cell-sap is of course taken up by the protoplasm, the nucleus, the cell-wall (comp. p. 244), and certain granular portions of the cell-contents which have yet to be described. In combination with these the cell-sap undergoes further changes.

The vacuoles may therefore be regarded as reservoirs, from which fluid matter may be obtained by other parts of the cell as necessity requires. That such is really the case is evident from the fact that the vacuoles in a cell vary much in size and number, gradually shrinking or suddenly disappearing according as their contents are slowly or rapidly absorbed by the protoplasm. On the other hand, again, surplus fluid matter drains off from the protoplasm and elsewhere, and increases the size and number of vacuoles.

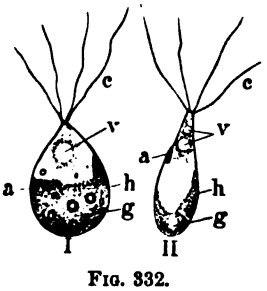


FIG. 332.

Inconstant vacuoles in macrozoöspores of Algæ (I. *Ulothrix zonata*; II. *Draparnaldia plumosa*). *c* Cilia (see below), *v* Vacuoles, *a* Red spot, *g* Green plasma, *h* Membranous outer layer; 300 times enlarged. — (From a drawing by Professor Dodel-Port.)

The increase and diminution in the size and number of vacuoles may readily be observed in the Amœba (see p. 244). As the naked mass of protoplasm moves about in the water, pushing out its tiny pseudopodia in all directions, vacuoles may often be seen to appear suddenly in the neighbourhood of the nucleus. These rapidly increase in size, but suddenly disappear as their fluid contents are absorbed by the granular protoplasm, or partly expelled.

After a time a vacuole again appears at some other part of the organism, only to have its contents absorbed as before, this process being continually repeated as long as the Amœba continues to live. The vacuoles of many Algæ (see below) are also inconstant. Two such may be seen in Fig. 332. The vacuoles (*v*) are shown at the pointed end of each cell, I. containing one vacuole, II. two. In the latter (a spore of *Draparnaldia plumosa*) each vacuole takes some twenty-eight or thirty seconds to reach its full size, and one or other of them disappears every fourteen seconds.

B. *Protoplasm.*

Protoplasm is found in every vegetable cell, and is indispensable to its life. All cells which do not contain protoplasm are dead.

Protoplasm consists of various kinds of *organic matter* and *water*. These form a clear, colourless, transparent substance, composed mainly of albuminous matters. Throughout this substance (protoplasm proper) are scattered numerous *granules* of various sizes, which give to protoplasm its familiar granular and somewhat turbid appearance (Fig. 323). Most probably these granules for the most part consist of *fatty* matter.

Besides these, protoplasm frequently contains other substances, *e.g.*, soluble *carbohydrates* (comp. p. 244), such as sugar, gum, and the so-called *plastic materials*, which later on separate from the protoplasm, penetrate the cell-wall, and cause its growth by intussusception.

The most important constituent of protoplasm is albumen. The albuminoid or proteids are organic combinations, built up, so far as is known, only by plants. They always consist of carbon, hydrogen, oxygen, nitrogen, and sulphur, the presence of the last two elements essentially distinguishing them from the carbo-hydrates already mentioned (comp. p. 244). The albuminoids contain about 54 per cent. carbon, 7 per cent. hydrogen, 16 per cent. nitrogen, 22 per cent. oxygen, and 1 per cent. sulphur. These figures, however, are only approximate, pure vegetable albumen not having as yet been obtained. The constant occurrence of a small quantity of sulphur (from ·8 to 2 per cent.) in albumen is worthy of note. All albuminoids are soluble in water under ordinary circumstances, but under certain conditions (*e.g.*, in combination with alcohol) they coagulate and form thick white masses not soluble in water.

As regards its physical properties, especially when viewed as a whole, protoplasm is exceedingly difficult to define, being neither a fluid nor a solid. If highly saturated with water, it is almost of fluid consistency, while in other circumstances it may

be slimy, mucilaginous, or even horny. It may perhaps be most fitly compared to soft wax. Like this under the influence of different degrees of heat, protoplasm, under suitable conditions, may assume all states between the perfectly solid and the perfectly fluid: it is a highly *plastic* substance (comp. p. 243).

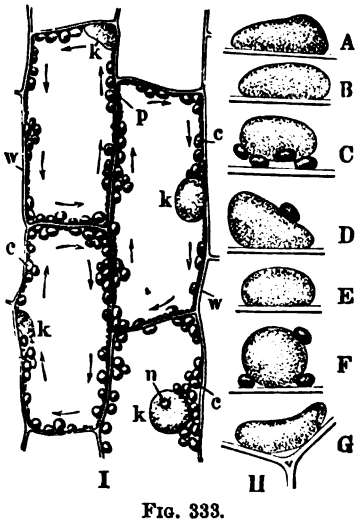


FIG. 333.

I. Cells with rotating protoplasm from a leaf of *Vallisneria spiralis*. *w* Cell membrane, *p* Protoplasm, *c* Chlorophyll granules, *k* Nucleus, *n* Nucleolus. (The arrows show the direction in which the protoplasm moves in each cell.) II. Nucleus from the upper cell to the right. *A G* Different forms assumed by the nucleus during twenty-six seconds. I. 600 times enlarged; II. 1000 times enlarged.

Living protoplasm is constantly in motion, even that which under the microscope seems to us to be at rest in the cell. The constant absorption of fluid matter from the vacuoles, and its separation again from the general mass of the protoplasm for the formation of the cell-wall and other solid tissues, are in themselves sufficient to exclude the possibility of permanent rest. Besides the motion thus originated, however, the protoplasm in a cell is frequently seen to be moving in a certain definite direction, as may easily be made out under the microscope. The protrusion of pseudopodia by the Amœba (p. 244), and the so-called *rotation* and *circulation* of protoplasm, are to be classed under this head.

The rotation of protoplasm may be well seen in the cylindrical cells of the leaf of *Vallisneria spiralis* (Fig. 333). In longitudinal section, the cells are seen to be rectangular. They are surrounded by a delicate membrane (*w*), and are completely filled with transparent protoplasm. Each contains a large nucleus (*k*, comp. p. 243) found adherent to some part of the cell-wall, and numerous small green granules, to which the beautiful green colour of the leaf is due (*c*, chlorophyll granules, see below); these, too, are all found in connection with the cell-wall. The protoplasm (*p*) moves round the cell in the direction

indicated by the arrows. In each cell there is an independent stream, which always moves in the same given direction, bearing with it the nucleus and chlorophyll granules. These are thus carried round and round the inner surface of the cell-wall, pushed over and under each other, and brought into new positions. Each circuit takes about thirty seconds.

Circulation of protoplasm may be studied in the hair-cells of Tradescantia (Fig. 323, *a*, *p*). In these the layer of protoplasm immediately under the cell-wall gives off numerous thread-like processes, which pass inwards, and divide the cavity of the cell into a number of spaces, each of which is filled with sap (*s s*). The threads contain many small colourless granules, which pass down one side of a thread (say the right) and up the other (the left). Owing to variations in the rate of flow of the current, a thread may be increased or diminished in thickness, split into several branches, or amalgamated with another. Sometimes the granules are deposited on the interior of the cell-wall, sometimes they are all, or nearly all, swept away from it; so that it, too, is subject to temporary variations in thickness. The aspect of cells which contain protoplasm in circulation is thus constantly changing.

The *distribution of protoplasm* in the cell depends on the age of the cell, its position in the plant, its functional use, and other often very variable conditions. In the earliest stages of growth the cell is completely and compactly filled with protoplasm. Later on, however, as it increases in size, vacuoles or sap-cavities are formed, until at length the cell becomes one large sap-cavity, as it were, surrounded by a thin layer of protoplasm. On the surface of the protoplasm, where it lies in contact with the inner surface of the cell-wall, a thicker and firmer layer is usually developed, which becomes visible as a delicate, colourless line, free of granules, when the protoplasm is so treated as to cause its separation from the cell-wall (Fig. 323, III.). If, however, the cell is full-grown, and no longer capable of division (see below), the protoplasm often shrinks to such a degree as to form an excessively thin, or even invisible, layer lining the cell-wall. When the cell is treated with a water-absorbing solution this may be again distinguished, as showing a fine double line.

C. *The Nucleus.*

One of the normal cell-contents is the nucleus, which lies imbedded in the protoplasm, usually close to the cell-wall. Its presence, like that of protoplasm, is an indication that the cell was a living one. In chemical composition it resembles protoplasm, from which indeed it is mainly distinguished by certain physical peculiarities. It is spherical or elliptical in shape, and consists of a much thickened mass of protoplasm.

Even in the earliest stages of growth the nucleus is present in the cell. In young cells, indeed, it is very conspicuous, its size being almost equal to that which it attains when full-grown (Fig. 323, II.). Growth takes place much more rapidly and to a much greater extent in the cell than in the nucleus, so that the larger the former grows, the smaller does the latter become in proportion. The nucleus has the power of moving from one part of the cell to another, as is evident from the fact that, while commonly found close to the cell-wall (*i.e.*, at the side, see Fig. 323, II., *k*, below; Fig. 333, *k*), immediately before division it is found in the centre of the cell, where it remains supported by numerous bands of protoplasm (Fig. 323, II., *n*).

The nucleus is surrounded by a delicate outer layer, which is reabsorbed at the time of division (see below). Within this is a homogeneous protoplasmic substance or sap in which are suspended numerous granules of considerable size. These granules are usually arranged for the most part round the circumference of the nucleus. On the surface or within the nucleus is the *nucleolus*, which is a granule distinguished from the others by its superior size (see *n*, Fig. 323, 333). Occasionally several or many nucleoli are to be found.

It can readily be made out from a study of those cells in which we find rotation of the protoplasm taking place, that the nucleus is not a solid but a plastic body. In these it can be seen to change its shape as it is carried round by the current, so as to suit itself to the variations of pressure to which it is subjected in coming into contact with other granules. Fig. 333, *A* to *G*, shows the various shapes assumed by the nucleus of a cell of the leaf of *Vallisneria spiralis*, during a single revolution of the protoplasm (time twenty-six seconds).

5.—Other Cell-Contents.

While cell-sap, protoplasm, and the nucleus regularly form a part of the contents of all living cells, there are other granular or partly solid matters which are restricted to certain special sets of cells, and are necessary only for the performance of special vital functions, or are the result of a special kind of vital activity. Of these we must notice, first, *chlorophyll* corpuscles and *starch granules;* secondly, *protein granules, inulin,* and *crystals.*

A. *Chlorophyll Corpuscles.*

The green colour peculiar to certain parts of plants, and not found in animals, is due to the presence of chlorophyll corpuscles in all or certain of the cells of which such parts are composed. Cells containing chlorophyll are found in all plants with the exception of the fungi, none of which have as yet been found to contain any true green colouring matter.

Chlorophyll assumes the form either of rounded granules, bands, or irregular masses. The latter forms are specially well seen in many filiform Algæ, particularly in the genus *Spirogyra* (Fig. 334). In these the chlorophyll masses pass along the cylindrical cells as two intertwining spiral bands. The spirals of chlorophyll in *Spirogyra* are shown in Fig. 334, the rest of the cell-contents being omitted.

Fig. 334.

Spiral chlorophyll bands in the cell of *Spirogyra.* 300 times enlarged.

In most plants the chlorophyll corpuscles are rounded, elliptical, or oval in shape (Fig. 335), when they can easily be distinguished, unless too closely packed together. The cells of some plants contain only a few or even a single chlorophyll corpuscle. In the latter case the corpuscle is, of course, very large. Usually, however, the cell contains a large number of corpuscles, which either occupy the entire cell or lie close together round the inner surface of its wall. They are always imbedded in the protoplasm, and are never found in the vacuoles.

The substance of which the chlorophyll corpuscle consists is similar to, if not indeed identical with, protoplasm. It differs, however, from ordinary protoplasm in having no granules

scattered through it. The corpuscle is not hard and brittle, but soft and plastic, and is throughout of a beautiful green colour, due to the presence of chlorophyll in its substance. The chlorophyll may be extracted by means of benzoline, ether, or absolute alcohol, and the protoplasmic matrix in which it was

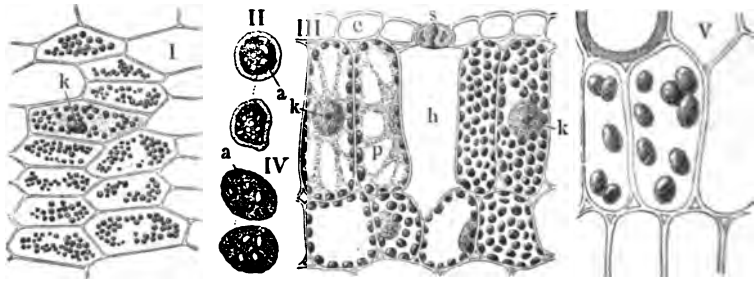


FIG. 335.

Cells with chlorophyll granules.—I. From the leaf of *Marchantia polymorpha;* 200 times enlarged. II. Do. single granules; 900 times enlarged. III. Do. from the leaf of the garden bean (*Vicia Faba*); 300 times enlarged. IV. Do. single granules; 900 times enlarged. V. From the leaf of a banana (*Strelitzia Nicolai*); 300 times enlarged. *k* Nucleus, *p* Protoplasm, *a* Starch granules, *e* Epidermis, *s* Stoma, *h* Air-space (see p. 282, *h*).

held suspended left colourless. If green parts of the plant are steeped in alcohol, they lose their colour in a few days, while the alcohol (at least in the dark) assumes a beautiful green tint.

According to recent investigations the following is the structure of the chlorophyll grain:—The protoplasmic matrix is of spongy texture, and forms a toughish framework, honey-combed by innumerable minute cavities. The interstices of this framework are everywhere permeated by an oily fluid called *hypochlorin*, which may be extracted by proper treatment, and is found to be of a somewhat crystalline nature. The green colouring matter is held in solution in this oil.

The chlorophyll corpuscles are at first extremely small, but increase in size as they grow older. Finally they divide, two corpuscles thus appearing in place of one.

In most plants *starch granules* are formed within the chlorophyll corpuscles (Fig. 335, II., IV. *a*). These appear at first as minute points, which gradually increase in size as the corpuscle grows older. Usually there are several starch granules contained in one chlorophyll corpuscle, and these as they grow appropriate almost all its contained space, its green protoplasmic contents being reduced to a thin, filmy envelope.

It would seem that the starch granules are formed from the hypochlorin of the chlorophyll corpuscles. To this statement the bananas form an exception, the oil contained in their chlorophyll corpuscles never being elaborated into starch (Fig. 335, V.).

In certain stages of the plant's life the chlorophyll grains decay and disappear. In most trees, &c. this happens in autumn, and shows itself in the change of colour of the leaves previous to their falling off. The starch granules are then converted into a saccharine fluid, in which form they are conveyed to the trunk, where they are again transformed into starch, and stored up in the permanent tissues of the plant. Meanwhile the green colouring matter decomposes, its place being taken by yellow or orange coloured granules, or a reddish fluid. To these changes are due the brilliant tints assumed by fading leaves.

B. *Starch Granules.*

The cell-contents hitherto considered have been of a more or less fluid nature. In the starch granules we now for the first time meet with the truly solid contents of the cell.

Starch granules are usually formed in full-grown cells; they represent the surplus of the nutritive material elaborated by the plant, which is stored up for the formation of new tissue later on. Every cell containing starch granules forms, therefore, a store of food upon which the plant may draw whenever necessity requires.

Starch granules (Fig. 336) are elaborated from protoplasm, in which starch-forming materials are held in solution. The granule orginates as an extremely small, rounded body, and increases in size by intussusception.[1] When fully grown it is marked by concentric striæ, indicating the laminæ of which it is composed. These laminæ are alternately of more or less fluid consistence, and are arranged around the centre of growth, which is usually a somewhat eccentric point, as growth does not take place equally in all directions. Hence, too, starch granules are usually oval in shape (Fig. 336, II.). Rounded and lenticular granules are, however, also met with (Fig. 336, III.), as are also granules of irregular shape (*e.g.*, in the milky juice of Euphorbias). When the starch granules are much crowded together in a cell, they press on one another in developing, and consequently assume a polyhedral form.

[1] See p. 246, note.

Under the microscope the starch granule presents an entirely colourless appearance; it consists of a loose framework of a

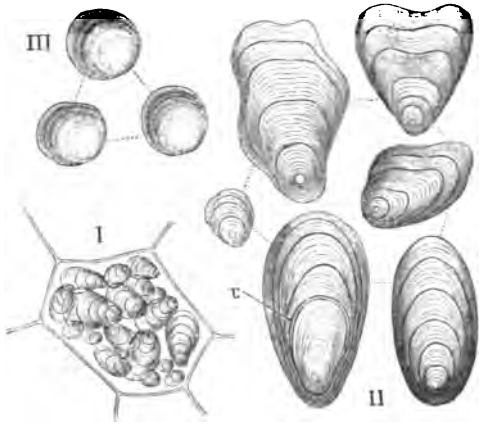


FIG. 336.

Starch Granules.—I. Parenchyma cell from the tuber of the potato (*Solanum tuberosum*), crowded with starch granules: 150 times enlarged. II. Single granules from the same cell, showing the laminæ (at a crack); 600 times enlarged. III. Starch granules from the endosperm (albumen, comp. p. 78) of wheat (*Triticum vulgare*); 600 times enlarged.

cellulose-like substance called *starch-cellulose*, and of a second substance called *granulose*, which is deposited on or about this framework. Granulose constitutes the starch proper.

Starch or amylum ($C_6H_{10}O_5$) is a carbohydrate (comp. p. 244) of the same chemical composition as cellulose, a substance into which it appears capable of being readily transformed. Starch is a white powder (potato starch) which, when properly treated (*e.g.*, with diluted sulphuric acid), first becomes soluble, and finally is transformed into sugar (grape-sugar). The conversion of starch into grape-sugar takes place within the chlorophyll corpuscles (p. 262) in the dark. On the addition of water, the envelopes of the starch granules burst when the temperature is raised to 50° or 60° C. The granules are then enabled to absorb a large quantity of water, and swell up into a structureless jelly-like mass. Starch granules may be rendered readily distinguishable under the microscope by the addition of a drop of solution of iodine in iodide of potassium. The starch granules then become dark blue, or almost black in colour, unlike any other constituent of vegetable tissue. This solution is thus a characteristic reagent for starch.

The starch-cellulose and granulose of starch are capable of separation by soaking in saliva kept at a temperature of 50° or 60° C. In some cases a few hours will suffice to effect the separation, in others the process takes several days. The saliva dissolves out the granulose, and the starch-cellulose framework is left behind. The latter will not form a jelly, and is rendered yellow, not blue, by the action of iodine.

In course of time starch granules are disintegrated, or converted into soluble starch (dextrin). In many cases this takes place by the reabsorption of the laminæ from the surface inwards. In others the disintegration goes on irregularly, and the grain assumes a worm-eaten appearance. Occasionally, too, disintegration proceeds from the centre to the surface instead of from the surface to the centre, as commonly happens.

Starch is a substance universally diffused in the various organs of the plant; it will come up again for consideration later.

C. *Protein Granules, Inulin, and Crystals.*

(1.) *Protein or Aleurone Granules* are chiefly found in the cotyledons of mature seeds, and, like starch, form a reserve store of nutritive material. They consist of small grains of albuminous substance, and are therefore in chemical composition closely allied to protoplasm. The protein granules often contain crystals of calcium oxalate (see below), and always a certain number of globose masses of magnesium phosphate. Protein granules are utilised by the plant in much the same way as starch granules. As the seed develops they dissolve, and are carried in solution to those parts where growth is taking place most actively, where they are built up into the tissues of the plant. They frequently enter into combination with starch granules in the same cell (*e.g.*, in the cotyledon of the pea).

(2.) *Inulin* is a starch-like substance abundant in the root-cells of many plants, particularly in those of Compositæ. It is chiefly interesting from the fact that, unlike the cell-contents we have hitherto considered, it forms part, not of the protoplasm, but of the cell-sap. It exists in solution in cell-sap, from which, however, it may be precipitated in the form of rounded crystals (see Fig. 337).

Inulin is obtained from the tissues containing it (*e.g.*, the tubers of the sunflower, dandelion, dahlia, &c.) by steeping these in alcohol. The inulin is then precipitated in the form of minute crystals, which are rendered more distinct by the addition of water (Fig. 337).

(3.) *Crystals.*—Crystals form a very common constituent in the contents of the vegetable cell. They consist for the most part of oxalate, or of carbonate of calcium, and assume the most diverse shapes. They appear either singly (Fig. 338, I., II.) or in aggregate masses (III.). Frequently they are needle-shaped,

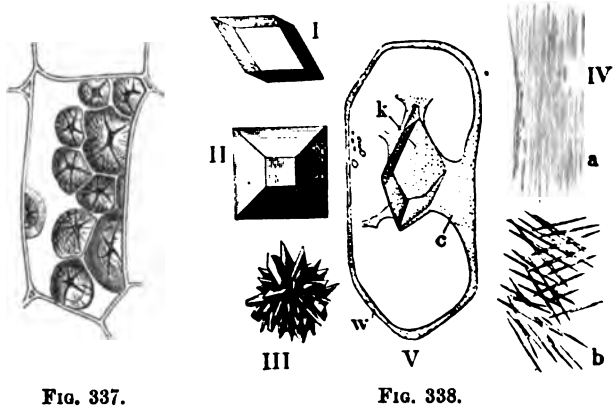


FIG. 337. FIG. 338.

Fig. 337.—Rounded crystals of *inulin* in a cell of the dahlia-bulb (*Dahlia variabilis*); 500 times enlarged (after Sachs). Fig. 338.—Crystals from vegetable cells: I. Of carbonate of calcium (rhomboidal). II.-V. Of oxalate of calcium. II. Four to eight sided, with truncated ends. III. Crystal from the nectary of *Malva*; 600 times enlarged. IV. *a b*, Crystals from the leaf of the fuchsia; 450 times enlarged. V. Cell from the pulp of the rose fruit, in the centre a crystal (*k*), supported by bands of cellulose (*c*). (V. after Poulsen).

and arranged in dense bundles parallel to the long axis of the cell. Such crystals used to be termed raphides; they occur in the leaves of the fuchsia, in most species of cactus, &c. Occasionally large crystals are found occupying the centre of the cell, where they are supported by processes from the cell-wall (V.). Finally, crystals are sometimes found in the cell-wall itself, *e.g.*, the silica crystals already referred to (p. 248), and the calcareous crystals of the Coniferæ. The incorporation of calcareous crystals in the cell-walls of other monocotyledons and dicotyledons is not very common.

6.—ORIGIN OF CELLS.

The growth of the plant is effected not only by the individual enlargement of the cells of which all its tissues are composed, but by their increase in number.

The cell is at first extremely minute, and shows little or no differentiation of parts. The thin outer membrane encloses a nucleated mass of protoplasm in constant movement. Later on, the protoplasm shrinks, and becomes small in mass compared with the cell-sap. As this takes place, the cells become specialised for the performance of their allotted physiological function, those especially rich in chlorophyll acting for the elaboration of new nutritive material, those especially rich in starch for the storing up of the surplus supply.

Cells in the earliest stages of growth are remarkable above all others for their power of division. Cell-division takes place in geometrical progression. First, the parent cell divides into two;

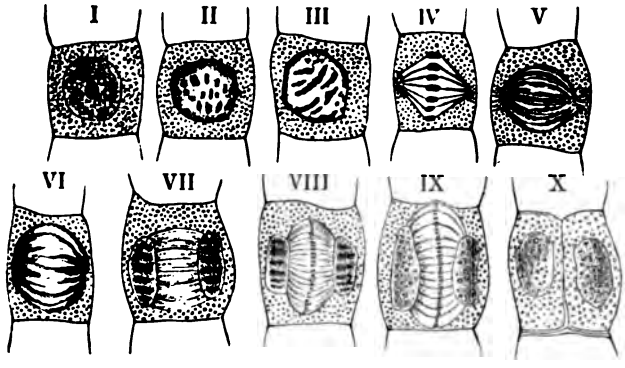


FIG. 339.

Cell-division.—Origin of guard-cells of the stomata in the leaf of *Iris pumila* (for explanation see text). 880 times enlarged. —(After Strasburger.)

these again each divide into two and so on, until the single cell becomes a tissue.

New cells may be formed in different ways. With a few exceptions, which will be noticed later on (Part V.), new cells arise by *division* or *segmentation* (of a parent cell), by *free-cell formation*, or by *conjugation*.

(1.) *Cell-Division or Segmentation.*—Cell-division is always preceded by certain peculiar changes in the nucleus (comp. p. 260), that structure being in fact chiefly concerned in the process. In the absence of the nucleus, no division could take place; all cells capable of division are nucleated. The process of cell-division is very beautifully illustrated in the development

of the guard cells on either side of the stomata in the leaves of monocotyledons (Fig. 339). Shortly before division the parent cell presents the appearance shown in I. It is uniformly filled with granular protoplasm, and the nucleus is as yet in a state of rest; in the latter the outer envelope, two nucleoli, and granular contents are to be distinguished. The first sign of approaching division is seen in the granules of the nucleus, which first become coarse (II.), and afterwards assume a curved, rod-like form (III.), while the outer envelope disappears. Next the nucleus becomes spindle-shaped, and its granular contents collect at its centre in the form of a plate or band,—the *nuclear plate*. The two halves of the nucleus each appear to be composed of a bundle of threads radiating from the pointed end towards the centre (IV.). Division now takes place across the nuclear plate, and the granular protoplasm separates into two masses (V.). These collect at either end of the nucleus, and maintain a connection by means of numerous delicate protoplasmic threads (VI.). Each mass next develops an investing membrane, and the cell presents the appearance of having two distinct nuclei, connected with one another by threads of protoplasm (VII.), their rod-like appearance being still distinctly visible.

With the division of the nucleus the first stage of segmentation is complete, and the second stage, the division of the cell itself, now commences. The threads connecting the two nuclei spread out in the middle towards either side, a layer of minute granules appearing across the part where this extension is most marked (VIII.). These granules are derived from the cell plasma, and become incorporated with the connecting threads. The threads continue to extend until they, and with them the granular layer or *cell-plate*, meet the wall of the parent cell (IX.). The granules of the cell-plate at first consist of starch, being coloured blue by iodine. They are rapidly transformed into cellulose, however, when the plate assumes a homogeneous appearance, and becomes the primary external membrane of the new cell (X.). The new cell-membrane usually possesses the property of permeability in a high degree. With the development of the cell-wall, the mass of threads connecting it with the nuclei disappear, and the contents of these are now seen to resemble those of the nucleus of the original cell (see IX. and X.).

(2.) *Free Cell Formation.*—Another mode of cell multiplication is that by which a large number of young cells are simultaneously developed from a single parent cell, as regularly happens in the case of many Algæ. By way of example we shall here consider the so-called *spores* of *Botrydium granulatum*, an alga already described and depicted on p. 250. A specimen of *Botrydium* being kept in water for some days, the earth can easily be removed from its roots (*w*) without injury to the plant, which is then ready for examination under the microscope. If kept on the slide in a drop of water, the membrane surrounding the balloon-like head (*a*) is observed gradually to thicken and swell up, showing meanwhile distinct traces of lamination (Fig. 340, I.). At the same time the protoplasmic contents get broken up into minute portions, which, owing to their great number, cannot

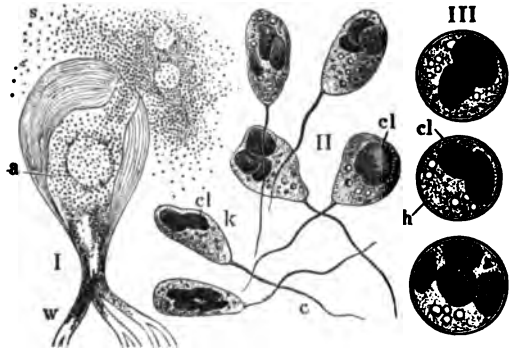


FIG. 340.

Zoöspores of Botrydium granulatum. — I. The cell with spores issuing from it, fifteen times enlarged; II. Spores in motion, fifteen minutes after leaving the parent cell; III. Spores at rest—the cilia gone, 1000 times enlarged. *a* Part of alga above the surface; *w* Root; *c* Cilia; *b* Cell-wall; *cl* chlorophyll corpuscles.

at first be really distinguished from each other. During the night the distended membrane of the parent cell finally gives way at one point or another, and the young cells are set free (*s*). The whole mass is in a state of active motion, each individual spore continuing to swim about for some time. Each spore is surrounded by a delicate membrane, and is similar in shape to the parent cell. It contains a quantity of granular protoplasm, and from one to four large bright green chlorophyll corpuscles (*cl*, II.). At the pointed end of the cell is a long, colourless,

hair-like process, the *cilium*, by the vibration of which the organism is enabled to move hither and thither. On account of their ability to swim about freely like young animalcules, such ciliated cells are termed *zoöspores*.

After having continued in motion for some hours, the zoöspores eventually come to rest. They lose their cilia and become globular in shape; the cell-wall thickens (*b*, III.), and the active little organisms settle down to the normal stationary vegetable existence.

Fig. 327 (p. 250) represents a plant of *Botrydium granulatum*, as it appeared at eleven o'clock in the forenoon. The whole plant is there shown, the earth being entirely washed from its roots. Fig. 340, I., shows the upper portion of the same plant as it appeared at 2.15 next morning. The vesicles in the zoöspores are formed by portions of the watery cell-contents of *a*. In II. we have six active zoöspores as observed at 2.30 A.M., and in III. three zoöspores at rest, as seen at 9.30 A.M.

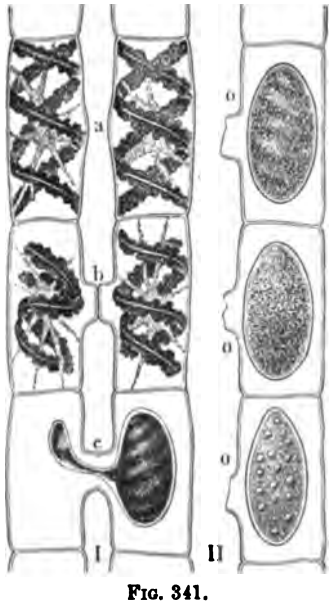


FIG. 341.

Conjugation in Spirogyra cells.—I. Two filaments ranged side by side; at *a* Processes are beginning to form; *b* Processes in contact; *c* Protoplasm passing from one cell to another. II. Filament after conjugation; *o o* Its cells in different stages; 450 times enlarged.

Conjugation.—This mode of cell-multiplication is characteristic of the filamentous Algæ, in which it may readily be studied. The filamentous Algæ are to be found in every ditch and pond, where, especially in spring, they are to be met with in the shape of greenish filmy or fleecy masses. They consist each of a thread composed of single cylindrical, elongated cells, placed end to end. Immediately before the process of conjugation takes place, two threads (*i.e.*, two plants) range themselves parallel to each other, so that their cells lie opposite and almost in contact. From the sides of every pair of cells processes next arise (Fig. 341, I., *a*), which grow out towards one another, until they finally meet (*b*). Their separation disappears, and direct communica-

tion is established between the interiors of the two cells (*c*). Meanwhile the contents of both sensibly contract, and collect into an egg-shaped mass. When the cells are placed in communication, the contents of the one pass over and mingle with those of the other, the two together forming an oval granular mass scarcely larger than the contracted contents of the single cell. The new mass of protoplasm (*o*, II.) becomes coated by a firm membrane, remains for a time unaltered, and finally develops into a new filament by the ordinary mode of division.

II.—VEGETABLE TISSUES (HISTOLOGY),

1.—Modes of Cell-Union.

In the foregoing chapters we have devoted ourselves to the consideration of the vegetable cell, its structure, origin, and development, without inquiring whether it, by itself, constituted the organism, or was only a part of the organism. We shall now see how cells unite to form the multicellular organism, and lose their individuality in the performance of functional activities for which the co-operation of a large number of similar cells is necessary.

Vegetable organs consisting of a single cell are rare, and are confined to the lowest groups. Such a unicellular plant is shown in Fig. 342, which represents an alga (*Closterium lunula*). The cell is enclosed in a firm membrane, is crescentic in shape, and contains numerous chlorophyll grains, with larger starch granules arranged in four rows. The nucleus is situated in the white spot at the centre, and at either end of the organism is a colourless vesicle, containing a number of minute crystals in constant vibratory motion. This tiny plant derives nourishment from the water in which it lives, and multiplies by a peculiar process of conjugation.

Fig. 342.

A unicellular alga (*Closterium lunula*), one of the Desmidiaceæ, 300 times enlarged.

Cells may unite to form a tissue in one or other of three ways, namely, by placing themselves in juxtaposition in one, two, or three directions.

When cells are attached to one another in one direction only, the result is a filament. Such an arrangement is seen in the

filamentous Algæ already mentioned (Fig. 334, Fig. 341), *e.g.*, Spirogyra, Zygnema, Conferva, Œdogonium, &c. The filaments occasionally branch, as in Cladophora, Bulbochæte, Chroölepus. In the higher plants, the filamentous arrangement of cells is found only in hairs and hair-like structures, *e.g.*, the staminal hairs of Tradescantia, the hairs of the Malvaceæ, &c.

Again, cells may unite to form a tissue by attaching themselves one to another in two directions. The tissue, then, has length and breadth, but has only the thickness of a single cell. Tissues of this kind are somewhat uncommon; the leaves of most mosses and scale-mosses may be taken as examples.

Finally, cells may unite to form a tissue by attaching themselves to each other in all three directions, as is the case with the tissues of all the higher plants. The tissue, then, has length, breadth, and thickness. The manner in which cells thus unite depends on the form of the individual cells, and on whether there are several or only one species of cell entering into the composition of the tissue.

Supposing that a tissue was composed entirely of cubical cells, these might then be arranged in layers so as to leave no interspaces between them. The same might occur if the cells were all regular three or six sided prisms.

If, however, the cells of a tissue are irregular or rounded in shape, smaller or larger spaces—*intercellular* spaces—will be left at the points where three or more meet. Fig. 343 represents a cell from the pith of the elder; *w w* are the common walls of this and adjacent cells; *i i* the intercellular spaces left where three cells meet. Here these are small and triangular; in other tissues, especially if composed of rounded cells, they are large, and three, four, or more sided (comp. Fig. 329, p. 253).

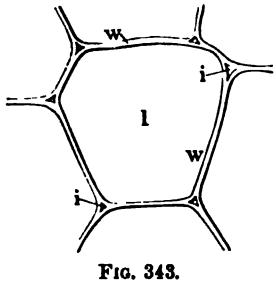


FIG. 343.

Cell from the pith of the elder (*Sambucus nigra*), 600 times enlarged. *l* Interior; *w* Cell-wall; *i* Intercellular spaces.

Another phenomenon, by no means uncommon in vegetable tissues, is the occurrence of *intercellular passages*. These are distinguished from intercellular spaces chiefly by their size. They form large cavities, the sides of which may be formed by four, six, eight, or more cells,

and serve for the passage either of air or sap through the tissues of the plant.

The intercellular passages are well seen in Fig. 344, which shows a portion of a cactus style (*Rhipsalis pachyptera*) in transverse section. That part of the tissue marked *c c* is composed of small polygonal cells, united so as to leave no interspaces either between one another, or between themselves and the adjoining vessels (*g*). A second portion (*p p*) is com-

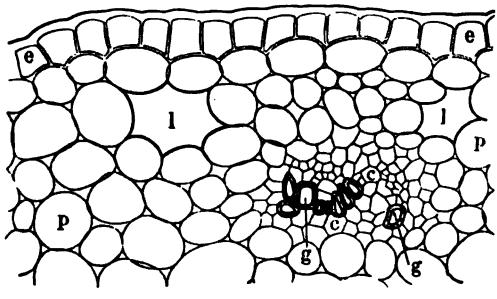


FIG. 344.

Tissue of a cactus style in transverse section (*Rhipsalis pachyptera*); 300 times enlarged. *e* Epidermis; *p* Fundamental parenchyma; *c* Prosenchyma cells with delicate external envelope; *g g* Groups of vessels; *l l* Intercellular passages.

posed of large rounded cells, between which intercellular spaces of moderate size occur. Here, too, are two large intercellular passages (*l l*); in this case they do not serve for the admission of air, but are filled with brownish coloured fluid.

The Common Cell-Wall.—As has already been mentioned (p. 267), the two young cells formed by division of a parent cell are separated from each other by a common membrane, which is formed, after the division of the nucleus, from the granular layer, dividing the protoplasmic threads which connect the two resulting nuclei. It therefore follows that each pair of adjacent cells are originally separated by a single common partition, and not, as was formerly assumed, by a double wall, of which one side is developed by one cell, the other by the second. This common partition, however, subsequently splits along its length, as is shown by the presence of the intercellular spaces (Fig. 343), and by the fact that when boiled many parenchyma cell-membranes are capable of being mechanically split up, as above

indicated. We are therefore justified in believing that the wall, originally common to two cells, becomes in the course of growth differentiated into two halves, each of which belongs to a separate cell.

2.—Tissues in the earliest Stages of Growth.

Among the higher plants the youngest or least developed parts are always found at the tip, new organs (leaves, flowers, &c.) always originating from that part of the growing shoot. In a section made through the leaf-bud of a tree, for example (see Fig. 22, *ante*, p. 17), we can easily distinguish the young axis (*a*). At its upper end is a rounded prominence, the youngest part of the plant, and that from which new organs are subsequently developed: this is the *growing point*. It is shown in the section of the horse-chestnut bud represented in Fig. 345.

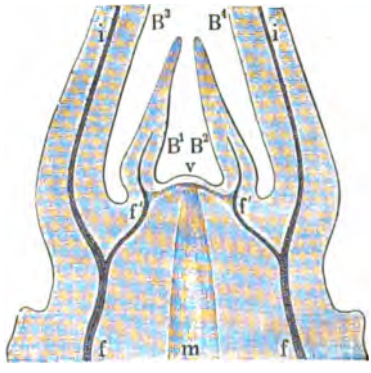


Fig. 345.

Section across the tip of the stem of a young horse-chestnut (*Æsculus Hippocastanum*); fifty times enlarged.—*v* Growing plant; B^1, B^2, B^3, B^4, the two youngest pairs of leaves; *f f i i* Vascular bundles of the second youngest; f^1 f^1 Vascular bundles of youngest; *m* Pith or medulla.

The growing point consists of a tissue of minute polygonal cells with unthickened walls. No intercellular spaces are present, and the process of division goes on with great activity. The cells are filled to overflowing with protoplasm, and certain large nuclei. Cells of diverse shape do not exist. Tissue of this kind has received the name *meristem*, or, from the fact of its forming the origin of all the other tissues of the plant, *primary meristem*. Fig. 346 shows the primary meristem of the receptacle of a flower of deadly nightshade (*Atropa belladonna*). The tissue is seen to be entirely formed of polygonal cells with unthickened walls. The cells in longitudinal section are four, five, or six sided. Not even the superficial layer (*o*) is differentiated from those underlying it.

To return to the growing point of the horse-chestnut. If the

part *v* in Fig. 345 be highly magnified, we find it to consist of tissue very similar to that just described as belonging to the receptacle of the flower of the deadly nightshade. The upper part is composed of the same polygonal cells, and there is the same want of differentiation in the superficial layer. Further down, however, we come upon a layer in which the cells differ in shape, and in the texture of their outer walls, from the preceding. They are arranged in vertical (*m m*) and horizontal (*f f*) rows, and are distinguished from the cells overlying by the greater thickness and strength of their walls. This is the beginning of the differentiation of the primary

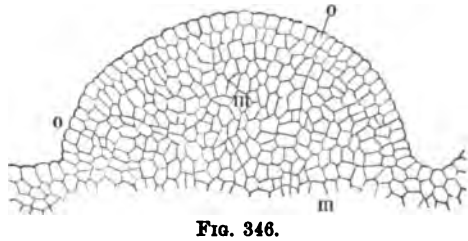


FIG. 346.

Meristem (*m*) from the receptacle of *Atropa belladonna*.—*o* Superficial layer ; 300 times enlarged.

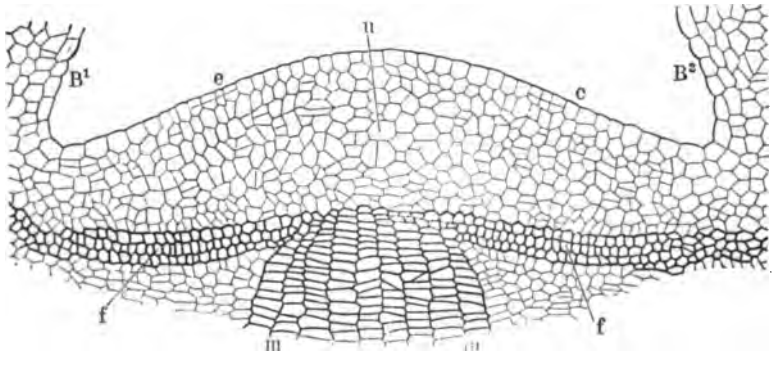


FIG. 347.

Longitudinal section through the growing point of the horse-chestnut (*Æsculus Hippocastanum*) ; 600 times enlarged.—B^1 B^2 Youngest pair of leaves ; *u* Undifferentiated meristem ; *e e* Superficial layer ; *m m* Cells forming the medulla ; *f f* Fibro-vascular bundles in course of development.

meristem into pith, vascular bundles, and cortex or rind, tissues with whose structure and function we shall become further acquainted by-and-by. The fact to be noted in the meantime is that *they all originate from the meristem.* It is difficult and often quite impossible to say where the meristem ends and the differentiated tissues begin, the transition from the one to the other is so gradual.

In the higher plants a considerable number of cells go to the formation of new organs, but in the lower forms (algæ, mosses, ferns, horsetails) these originate from a single cell. This common parent cell is found at the growing point of the young shoot, and is termed the apical cell. That of *Marsilia uncinata* (a plant related to the ferns) is shown in Fig. 348. Close beneath the growing point arise the youngest leaf-shoots, two of which are seen in Fig. I. At the end of each shoot is a large cell, the walls of which are rounded externally, but run down obliquely on the inside (*s s*). This is the apical cell; it is usually very distinctly nucleated. All the cells below the apical cell have developed from it in the order shown in Fig. 348, II. At the

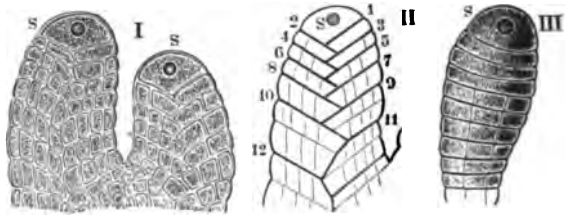


FIG. 348.

The apical cell.—Leaves of *Marsilia uncinata*. I. Two young leaves, viewed from the front; II. Diagrammatic representation of one of the same; III. Do. from the side. *s* Apical cell; 600 times enlarged.

point where the leaf is now found was originally only the large rounded apical cell; this in course of time divided, the wall 12 placing itself obliquely to its long axis. By-and-by the wall 11 was developed, so that the young leaf was now composed of three cells, the apical cell and two others derived from it. Division of the apical cell now continued, new cells being developed to the right and to the left alternately, in the order indicated by the numbers 10, 9, &c., 1 being the last to appear. In the event of further division taking place, a new cell would be formed parallel to 2. The secondary cells themselves divide into segments, and hence we have the complex assemblage of cells shown in I. III. is a shoot similar to I., but turned through an angle of 90°; the cell-walls are here seen only where they meet the surface of the young organ.

The development of the root takes place in a similar manner to that of those parts of the plant which appear above the

surface. In the higher plants the growing point is composed of a larger or smaller number of cells; in the lower plants, of a single apical cell. The subject will be further treated of in a subsequent chapter.

3.—The Systems of Tissues.

If a full-grown stem, say that of an herb, be cut across, we find it to consist of two sorts of tissue, very easy to distinguish from each other (Fig. 349). The tissue of which it is mainly composed is of uniform consistency, and is made up of rounded unlignified cells, with intercellular spaces between them (p. 272). This is the *parenchyma* or *fundamental tissue.*

Irregularly scattered through the fundamental tissue are numerous groups of cells, chiefly distinguished from the others by the fact that their walls are much thickened, and frequently lignified (*g*). In longitudinal section these are seen to be greatly elongated (comp. p. 250), the tissue which they form being termed *prosenchyma.* This tissue always contains vessels (comp. p. 250), which traverse the stem in the long direction, forming the *vascular* or *fibro-vascular bundles.*

The cells composing the superficial layer of fundamental

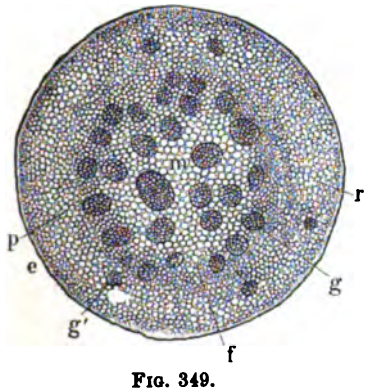


Fig. 349.

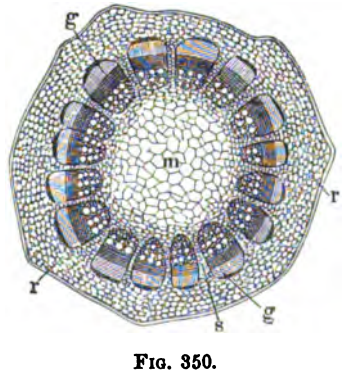


Fig. 350.

Fig. 349.—Transverse section of the stem of a monocotyledon (*Aspidistra elatior*). Fig. 350.—Do. of the stem of a dicotyledon (*Kerria japonica*); fifteen times enlarged. *e* Epidermis, *r* Rind, *m* Medulla, *g* Fibro-vascular bundles (in Fig. 349 scattered, in Fig. 350 arranged in a circle).

tissue (*e*) are distinguished from those underlying them by the superior thickness of their outer walls; they form the *epidermis* of the stem.

These three tissues, the *epidermis*, the *fundamental tissue*, and the *fibro-vascular bundles*, are found even in the simplest full-grown stems. We shall presently see, however, that in many, nay in most stems, these tissues develop in very different ways, and are each capable of distinction into different layers.

Distribution of the Fibro-vascular Bundles through the Fundamental Tissue (Monocotyledons and Dicotyledons).—In the higher or phanerogamous plants the fibro-vascular bundles are distributed through the fundamental tissue in two ways, the one peculiar to the monocotyledons (comp. pp. 100-102), the other to the dicotyledons (comp. pp. 115-116).

In the case of the monocotyledons (Fig. 349) the fibro-vascular bundles are seen in transverse section to be irregularly distributed through the stem, without being confined to any particular region.

In the dicotyledons, again (Fig. 350), the fibro-vascular bundles are seen in transverse section to be arranged in a circle round the central portion of the stem (*g*), and are placed (at least in full-grown stems) so close together that they divide the fundamental tissue into two well-defined parts,—the medulla (*m*) or central portion, and the cortex (*r*) or peripheral portion.

From the foregoing it is evident that the higher plants fall *naturally* into the two groups of monocotyledons and dicotyledons. We shall further see that the fibro-vascular bundles are also different in structure in the two classes.

4.—Epidermal Tissues.

All tissues forming the external investment of the vegetable organism are so modified as to withstand successfully variations of temperature, &c., which might prove injurious to the delicate underlying structures. We therefore find the epidermal tissues best developed in those organs which are most exposed to the injurious agencies above referred to.

As a rule, only the superficial layer of cells undergoes modification, cases in which the underlying layers also become modified being rare. Along with the *epidermis* proper, we shall consider the *hairs*, the *stomata*, and the *bark*.

A. *The Epidermis.*

The superficial layer in the stem, leaves, &c. is almost always distinguished from the subjacent layers by the peculiar develop-

ment of its cell-walls; it is termed the *epidermis*. The epidermis is always composed of cubical, prismatic, or flat-shaped parenchyma cells. They are commonly arranged in rows, in such a manner that the long axis of each cell corresponds with that

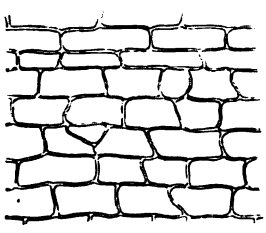


FIG. 351.

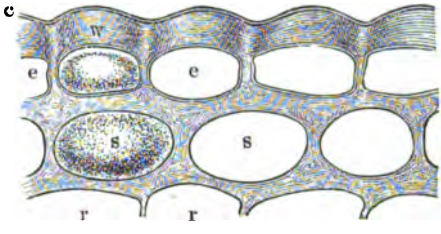


FIG. 352.

Fig. 351. — Epidermis cells from the leaf of *Strelitzia Nicolai*; removed by treating the leaf with boiling water; 200 times enlarged. Fig. 352.—The same from a one-year-old stem of *Kerria japonica*, in vertical section; 600 times enlarged. *e* Epidermis cells, *w* Thickened external surface, *c* Cuticle, *s* Subcutaneous layer, *r* cortical cells.

of the organ on whose surface it lies (Fig. 351). In cross-section the epidermal cells are quadratic or oval (*e*) in shape, and are on three sides enclosed by walls similar to those of ordinary cells. The fourth side, however (that, namely, which constitutes the outer surface), is very strongly developed; its thickness varying according to the toughness of the surface of the organ to which it belongs. The outermost portion of the cell-wall is invested by a delicate membrane which runs continuously over the whole epidermis. This membrane, the *cuticle*, is composed of a layer of cork substance (suberin, p. 248), and is frequently much corrugated.

The cuticle is of great service in relation to the circulation of sap in the plant. It is close and firm in texture, and has incorporated with its substance minute particles of resin or wax. The cuticle is capable of absorbing moisture resting on the surface of the organ it covers, while it prevents the sap contained in the tissues of the plant from passing out and being evaporated.

The layers of cells lying immediately below the epidermis sometimes differ from the rest of the fundamental tissue in a remarkable manner. Thus in Fig. 352 we see beneath the superficial epidermic layer a layer of cells with thickened walls (*s s*), under which we first meet with the usual thin-walled parenchyma cells (*r*). A layer of permeable collenchyma tissue is also sometimes found beneath the epidermis, the cells of which are similar to those already described on p. 246.

By peculiar modifications of individual epidermic cells, *hairs* and *stomata* are formed.

(1.) *Hairs.*—Hairs (comp. p. 79) originate by the extraordinary development of an epidermic cell in the long direction (Fig. 353). If during the development of the cell no internal division takes place, the hair is said to be unicellular (III.); in other cases it is said to be multicellular (I. and II.). Hairs vary much in shape. Unicellular hairs are usually cylindrical and *pointed*, while multicellular hairs are frequently *clavate*. If the terminal cells are rounded and much larger than the others, the hair is said to be *capitate*. *Stellate* hairs are those in which the cell from which they originate has become branched. *Prickles* are hairs composed of cells having lignified walls.

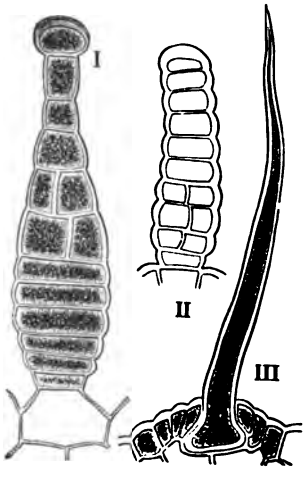


Fig. 353.

Hairs.—I. Multicellular capitate hair from the nectary of *Abutilon Hildebrandii*, 600 times enlarged; II. Multicellular; III. Unicellular hair from the style of a species of *Hibiscus*, 400 times enlarged. (In I. and III. the cell-contents are indicated.)

In many plants the cells constituting the hairs attain a considerable size, separate from the parent organism, and, under favourable circumstances, develop into new plants. This peculiar phenomenon is characteristic of many mosses. We shall here trace out the various steps of the process in a liver-wort, *Marchantia polymorpha* (Fig. 354).

Marchantia polymorpha is a delicate green, moss-like plant. It attains a length of several centimetres, and is attached to the ground by numerous thread-like roots which spring from its under surface. Besides the fruits, there sometimes appear on the surface of these plants tiny cup-like structures, containing numerous small cellular bodies. When full grown, the latter separate from the cups in which they have developed, and fall to the ground, where, if sufficiently supplied with light and moisture, they develop into new plants. They are technically termed gemmæ: their development is as follows:—A hair-cell—one of the epidermic cells forming the lining of the cup-like structure—begins to project above the other, and is divided in two by the partition *a* (I.). The cell is thus divided into a superior and an inferior half. Further division takes place in the superior half by the development of two more partitions parallel to *a* (*b*, *e*, II.), after which the vertical partition *d*. The process continues until the structure

assumes the form shown in IV. and V., the three original segments being marked by stronger lines. The superior half is now multicellular, while the inferior half (*f*) remains unicellular. In the next stage (VI.) the process of cell-division makes rapid progress, development, however, in the part between *b* and *c* not keeping pace with that of the rest of the tissue. This becomes gradually more and more marked (VII.), a depression being now distinctly discernible at the point above indicated. When nearly full grown the structure consists

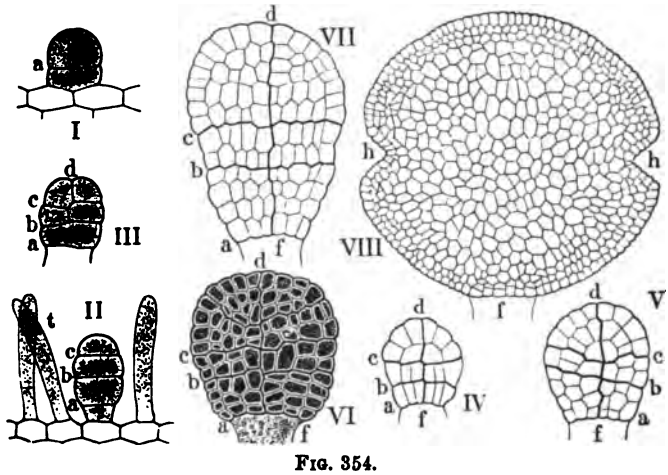


FIG. 354.

Development of gemmæ in Marchantia polymorpha.—I. Epidermic cells, upon which lies the apical cell from which the gemma is developed; the first two segments are already present, separated by a partition at *a*. II. The same, with two additional segments (*b c*) developed parallel to *a*. III. The same, showing the segments divided by a vertical partition, *d*. IV.-VII. Successive stages of development. The segments increase in number, the primary partitions being marked by stronger lines; the cell (*f*), upon which the whole structure rests, can now easily be distinguished. In VI. and VII. a multicellular tissue has been formed. In VIII. we have the full-grown gemma, composed of a tissue of parenchyma cells, and slightly cleft at *h* (*i.e.*, between the segments *b* and *c*). The cell-contents are indicated in I., II., III., and VI.; they are omitted in the other figures for the sake of clearness. I.-VII. 600 times enlarged; VIII. 200 times enlarged.

of a tissue of parenchyma cells, is rounded in shape, has two lateral indentations, *h h* (corresponding to *b c*), and is supported on the inferior cell, *f*. After separation from the cup, young shoots arise from the indentations.

From the foregoing it appears that the original hair-cell is similar to the apical cell already described (p. 276), and the process of development of the gemma of *Marchantia* resembles in many important respects the development of the leaves of *Marsilia*.

(2.) *Stomata.* — Stomata are to be found in the epidermis

of most green parts of the plant. When the epidermis is torn away from the under side of a leaf, we see, interspersed among the ordinary epidermic cells (*e*, Fig. 355), a number of crescent-shaped cells arranged in pairs opposite to one another. These are the stomata (*s*). They are found by hundreds in every leaf, and are distributed with more or less regularity. Thus, in the example shown in the figure (leaf of snowdrop), they always occur where the narrow ends of two epidermic cells come into contact.

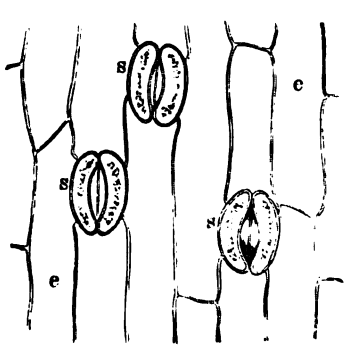


FIG 355.

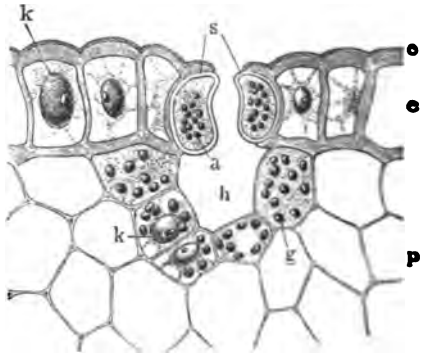


FIG. 356.

Stomata.—Fig. 355.—Portion of epidermis from the under side of the leaf of *Leucojum vernum*, 300 times enlarged. *e* Epidermic cells; *s* Guard-cells. Fig. 356.—Stomata in a transverse section of the ovary of *Agapanthus umbellatus*, 600 times enlarged. *s* The two guard-cells, containing protoplasm and starch granules (*a*); below, the air space (*h*), here bordered by five parenchyma cells (*p*), all containing chlorophyll corpuscles (*g*) and two of them with a nucleus; *e* Epidermic cells; *k* Large nuclei of do.; *c* Corrugated cuticle.

The stomata are formed by two symmetrical semilunar cells, called *guard-cells*. The concave surfaces of these are to a certain extent mobile, and capable of being approximated one to the other. When they meet the stoma is *closed*; when their concavity becomes more pronounced, the stoma is *open* (see *s*, Fig. 355).

A section passing through a stoma shows that the two guard-cells (*s*, Fig. 356) belong to the epidermic layer (*e*). The cells shown in the figure are in shape very like a bean, except that the end next the surface of the leaf is somewhat pointed. They contain granular protoplasm and starch grains (*a*, comp. p. 264). Between the two guard-cells is an intercellular space (comp. p. 272) forming an opening through the otherwise continuous epidermis,

and communicating directly with the deeper tissues of the leaf. Below, the opening widens out into a large cavity (*h*), bounded by the walls of a number of ordinary parenchyma cells (*p*). *By means of the stomata,* therefore, *direct communication is established between the interior of the leaf and the external world.* The communication is cut off when the stomata are closed.

Stomata are formed by the modification of epidermic cells. In the leaves of *Leucojum vernum* this modification takes place in the following manner :—By means of a transverse partition, a small portion at one end of an ordinary epidermic cell is shut off from the rest, and a smaller cubical cell is thus formed. This again becomes longitudinally divided into two halves (comp. p. 267), the position of the future stoma being indicated by a slight curvature of the cell-wall. Later on, the last-formed partition splits along its entire length (comp. p. 273), and the two lamellæ gradually grow further and further apart. The guard-cells afterwards become more rounded, and the development of the stoma is complete.

Stomata are almost entirely confined to the green parts of plants. They are especially characteristic of the leaves of the higher plants, appearing for the most part on their under surface. They are seldom or never found on the upper surface, except in the case of such water plants as have floating leaves (*Nymphæa, Hydrocharis*), the upper surface being then alone in contact with the air. Stomata also occur on such parts as the stems and ovaries (see Fig. 356) of plants, when these are coloured green ; they are not found in true roots.

The *function* (comp. p. 240) of the stomata is of great importance. When open they afford a passage for the admission of air to the vegetable tissues. These the air penetrates chiefly by means of the intercellular spaces. The intercellular spaces are lined by parenchyma cells, having excessively thin walls, and filled with chlorophyll. The air, passing through the cell-walls, reaches the chlorophyll granules, in which, by the action of sunlight, a very peculiar change is soon effected. The carbonic acid gas, of which atmospheric air contains about ·04%, unites with the water in the cell to form a carbohydrate—one of those chemical combinations which we have already seen (pp. 244 and 264) to be of great importance in the nourishment of vegetable tissue (*e.g.*, the formation of the cell-wall, &c.). In these cells therefore, an *organic* compound is elaborated from two *inorganic substances,* carbonic acid and water. As, however, the resulting carbohydrate contains less oxygen than carbonic acid and water

together, it follows that, in the process of combination, a considerable quantity of oxygen must be set free. This is returned to the atmosphere through the stomata. The process is therefore one of *deoxidation*. The absorption of carbonic acid by the cells, its elaboration into a carbohydrate, and the resulting liberation of oxygen, constitutes the process of "*assimilation*." This is not to be confounded with *respiration* (the taking up of oxygen, and giving off of carbonic acid), a process which is carried on among plants just as among animals (see below).

Of the details of the process of assimilation, as effected under the influence of sunlight in tissues containing chlorophyll, nothing is as yet known, and chemists have not yet succeeded in reproducing it artificially. Let us suppose starch ($C_6H_{10}O_5$) or sugar ($C_6H_{12}O_6$) to be the resulting product of assimilation, the process may then possibly be represented by such formulæ as the following :—

$$\underset{\text{Carbonic acid.}}{6\,CO_2} + \underset{\text{Water.}}{5\,H_2O} = \underset{\text{Starch.}}{C_6H_{10}O_5} + \underset{\text{Oxygen.}}{12\,O}$$

OR

$$\underset{\text{Carbonic acid.}}{6\,CO_2} + \underset{\text{Water.}}{6\,H_2O} = \underset{\text{Sugar.}}{C_6H_{12}O_6} + \underset{\text{Oxygen.}}{12\,O}$$

Recent investigations tend to show that hypochlorin (see p. 262) is the first product of assimilation from which starch, sugar, and other carbohydrates are afterwards elaborated.

FIG. 357.

Apparatus for demonstrating the liberation of oxygen from the green parts of plants.

The liberation of oxygen involved in the process of assimilation may be demonstrated by the following experiment (see Fig. 357). Let the end of the tube of a large funnel (*b*) be covered with an indiarubber band (*c*), over which is fitted a glass test-tube (*d*). Have ready a quantity of fresh green leaves mechanically freed of any air that might be adhering to them, by soaking for some time in water. Plunge the funnel into a bath containing distilled water, and fill the wide end with the leaves. Then, as shown in the figure, place the apparatus, wide end downwards in a glass vessel (*a*), and expose the whole to the action of sunlight

The process of assimilation is continued for some time in the leaves by means of the air enclosed in their air spaces. By-and-by air bubbles arise from the leaves, pass upwards, and collect in the test-tube. At the end of the experiment the presence of a large proportion of oxygen in the air occupying the space *e d*, may be demonstrated by the application of a glowing match, which, on being introduced into the test-tube, bursts into a flame.

As a rule stomata serve for the absorption and exhalation of gases, but in some cases the leaves of plants also contain openings for the discharge of fluids. Thus the submerged leaves of certain water-plants (*Callitriche*, *Hottonia*, *Batrachium*) have pores by which water is given off; similar pores are found at the tips of the teeth in the serrated edges of many leaves; these secrete a slimy fluid. Finally, the honey is discharged from the nectaries of many flowers by means of pores (comp. p. 182). In such cases the stomata form true organs of secretion.

B. *Cork.*

Besides the epidermis proper, and the structures in connection with it, we have to take account of the corky layer as one of the epidermic tissues. The formation of cork regularly occurs in such plants as attain considerable thickness, and are exposed to great variations of temperature (trees, &c.).

Fig. 358 represents the cortical system of a one-year-old stem of currant bush (*Ribes sanguineum*), as it appears in winter before the new sap begins to circulate. The stem is covered by very strong epidermis (*e*), beneath which are several layers of irregularly shaped cells (*r*), the walls of which become distorted during growth. Next comes the corky layer (*k*), which separates the bark from the bast (*b*).

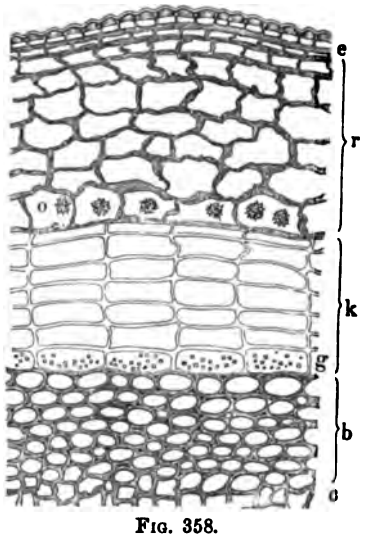


FIG. 358.

Outer Bark.—Transverse section of a one-year-old twig of *Ribes sanguineum*; 300 times enlarged. *e* Epidermis; *r* Sub-epidermis, the cells of the lowest layer containing crystals of calcium oxalate; *k* Cork, the cells of the lowest layer (*g*) containing chlorophyll; *b* bast-cells, passing gradually into layers of soft bast-cells. Appearance during winter.

The cortical layer is composed of several rows of tabular cells, arranged above one another

at right angles to the surface. Their walls are of moderate thickness, and meet one another without forming intercellular spaces. In physical properties the cork resembles the cuticle, being, like it, impermeable by water or air.

The corky layer increases in thickness by division of the lowermost rows of cells. Eventually a thick coat of this tissue is formed, which closely envelops the whole stem, and is called the *periderm*. As it develops, the overlying epidermis disappears, and the cork becomes the sole protective layer. While the older cork cells die, they are replaced by the division of the lowest layer of cells, the cork-cambium (Fig. 358, *g*). This constitutes the formation of the cork, which consists of large masses of tissue, and in certain plants periodically peels off in laminæ.

The surface of wounds in soft growing tissues usually gets coated over with cork, which prevents the injurious effects of exposure to the atmosphere.

5.—Fibro-Vascular Bundles.

While the lower plants consist solely of parenchyma, the higher plants are characterised by the presence in their fundamental tissue of prosenchyma cells and vessels. These are arranged so as to form strings or bundles, which run parallel to the long axis of the organ to which they belong. They constitute what is termed *vascular tissue, vascular bundles*, or *fibro-vascular bundles*. Plants which have no fibro-vascular bundles are termed *Thallophytes* (Fungi, Algæ, Lichens). In contradistinction to these plants in which fibro-vascular bundles are present, are termed *Cormophytes* (Ferns, Coniferæ, Phanerogams). The link between the Thallophytes and the Cormophytes is formed by the mosses or Muscineæ (liver-worts, bog-mosses, true mosses), in the stem of some of which a single incipient fibro-vascular bundle can be made out. In the higher plants the fibro-vascular bundles are arranged in two ways, as already indicated (p. 277); in the monocotyledons they are irregularly distributed through the fundamental tissue; in the dicotyledons and conifers they form a concentric circle. The ferns so far approach the mosses, inasmuch as their fibro-vascular bundle or bundles traverse the centre of the stem. In other plants related to the ferns (*e.g.*, the Equisetums, see below)

the fibro-vascular bundles are arranged in the same way as those of the dicotyledons and conifers.

The fibro-vascular bundles traverse the stem and roots in the long direction. In the former case they frequently anastomose. In many plants they may easily be distinguished with the naked eye, *e.g.* in the broken leaf-stalk of the plantain (*Plantago major*), where they appear as brownish threads. The vascular system of the stem is very complex, branches being given off at intervals to the leaf-stalks, leaves, and flowers. The venation of the leaves is formed by these vascular bundles and their branches.

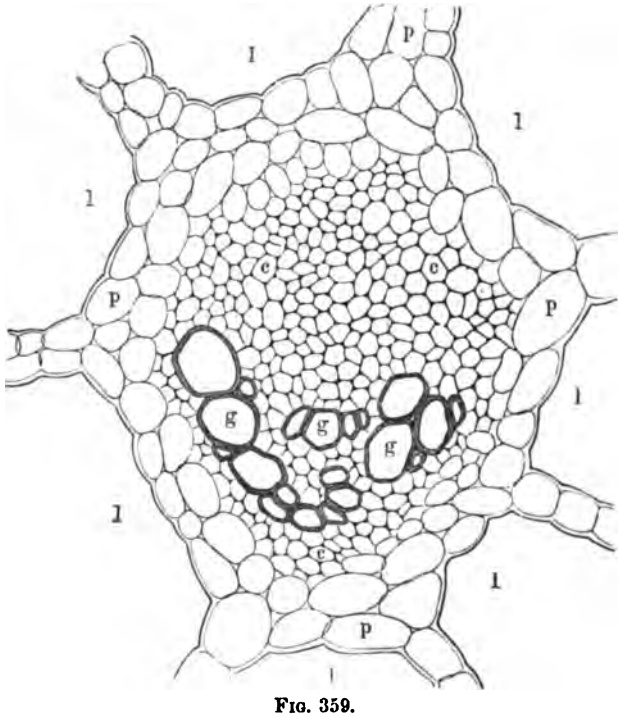


FIG. 359.

Simple fibro-vascular bundle from a Calamus stem (*Acorus Calamus*); transverse section, 300 times enlarged. *g g* Groups of vessels, *c c* Cambiform cells, *p p* Cellular tissue (parenchyma), *l l* Air spaces in the surrounding fundamental tissue.

Let us now examine a very simple fibro-vascular bundle (Fig. 344, p. 273; Fig. 359, transverse section). In the example here shown the cellular part of the bundle may be easily distinguished from the surrounding parenchyma with its rounded or elliptical cells, by the fact of its containing no intercellular spaces.

In such a bundle we see two main kinds of tissue. One is composed of small, polygonal cells, similar to those of the fundamental tissue forming the great bulk of the stem; the other consists of a number of larger, more rounded vessels, with thickened walls (*g g*). The former is styled *cambiform* tissue, the latter *vascular* tissue (comp. p. 254).

The two kinds of tissue may be seen still better in a longitudinal section (Fig. 360). The example here shown is very similar to that in Fig. 344; *p p* are the thin-walled, cylindrical cells of the fundamental tissue; *c c c*, the cambiform cells, *g g* are spiral vessels.

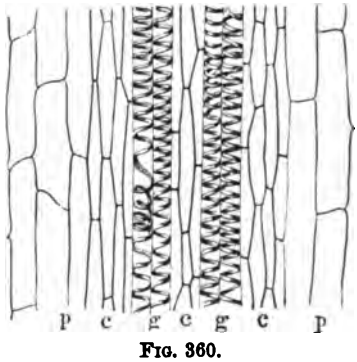


FIG. 360.

Simple fibro-vascular bundle from the style of *Cereus grandiflorus*; longitudinal section, 250 times enlarged. *g g* Vessels, *c c* Cambiform, *p p* Fundamental tissue.

The structure above described is characteristic only of very young and simple fibro-vascular bundles. These originally develop entirely from procambium cells, but as they grow older become much altered, particularly in the hardier portions of the plant (stem, trunk, &c.). Ultimately the structure of the fibro-vascular bundle is often very complex. The appearance of the fibro-vascular bundle in the later stages of growth depends on the manner of its development; it differs in monocotyledons and dicotyledons, at least so far as the bundles of the stem are concerned. Fibro-vascular bundles are accordingly divided into two classes, the *closed* or monocotyledonous, and the *open* or dicotyledonous.

(1.) *Closed* (*or Monocotyledonous*) *Fibro-vascular Bundles* (Fig. 361).—Closed bundles are entirely composed of permanent tissue, *i.e.*, tissue the cells of which are incapable of further multiplication by division. Closed bundles cannot therefore increase in breadth and thickness. Such a bundle is shown in Fig. 361; *p p* is the surrounding parenchyma composed of thin-walled cells, and containing large three and four sided intercellular spaces; *g g* is a group of vessels lying in connection with one another, and forming almost the extreme limit

of the bundle; these are thick walled and pitted, and enclose a portion of the permanent tissue (*c c*), another small part of which is found external to (*g g*) and is specially well seen at *d d*.

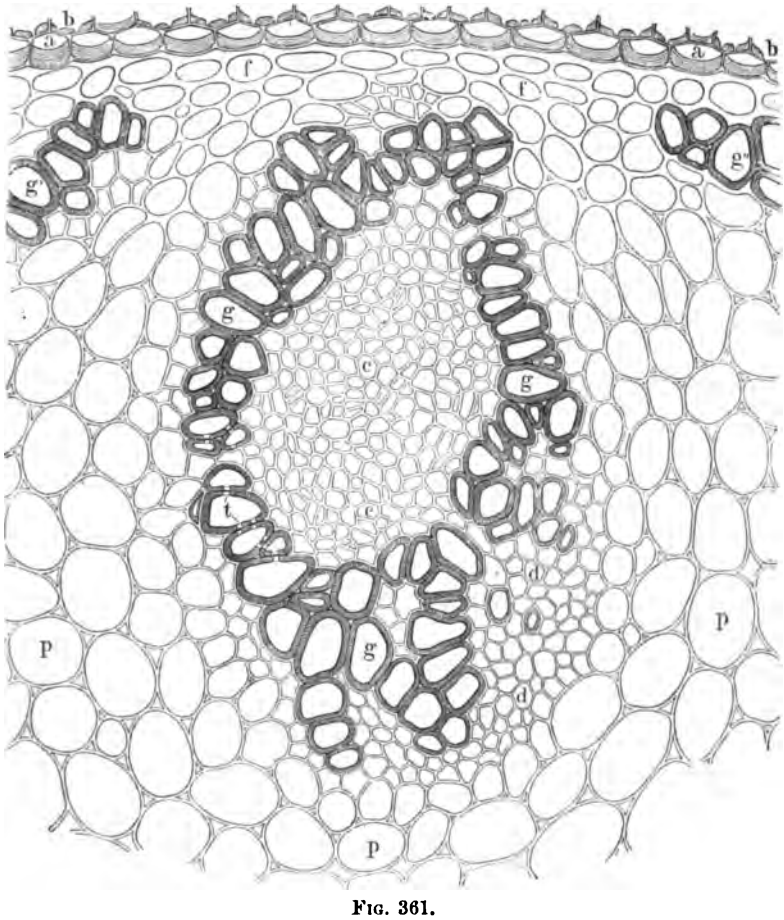


FIG. 361.

Closed fibro-vascular bundle from the rhizome of *Convallaria majalis*; transverse section; 450 times enlarged. *g g* Vessels forming the outer limit of the bundle (the pits are shown at *t*, but are omitted elsewhere); *c c* Permanent tissue, surrounded by vessels; *d d* Permanent tissue outside the vessels; *p p* Fundamental tissue, the cells of which have become thicker and smaller at *f f*; *a* Peripheral layer of parenchyma cells, with walls thickened on one side (comp. Fig. 329); *g' g''* Vessels belonging to other fibro-vascular bundles.

(2.) *Open* (*Dicotyledonous*) *Bundles* (Fig. 362).—On the whole, the structure of closed bundles is simple and easily understood;

that of open bundles is much more complex. In contrast to the former, open bundles contain a certain layer of cells which *retain their capability of multiplication by division.* These cells are situated in the centre of the bundle, which may accordingly

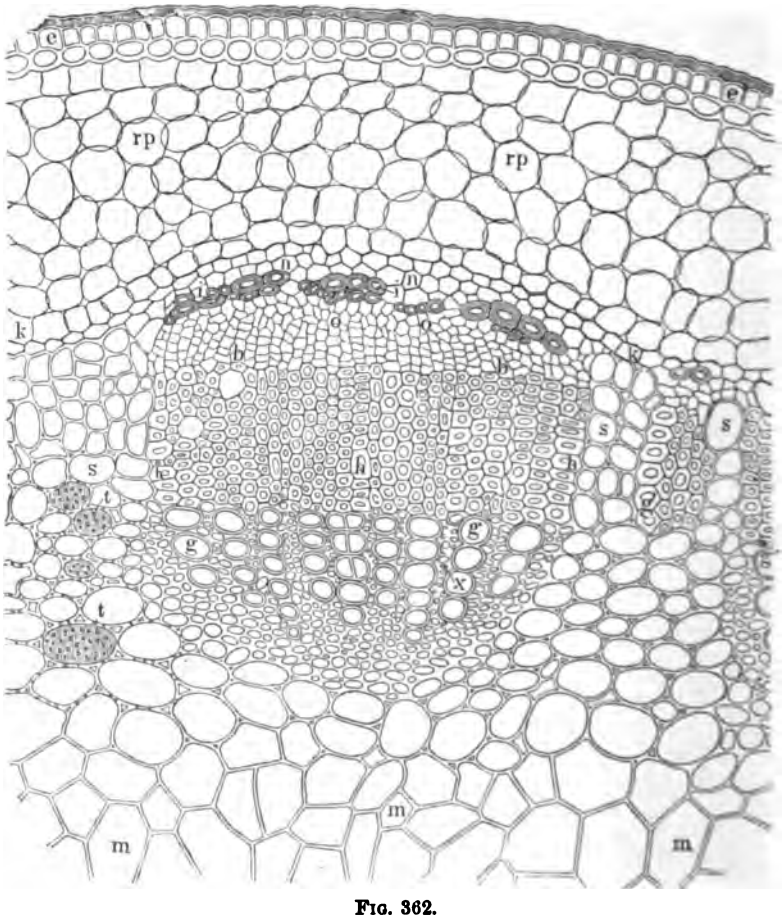


FIG. 362.

Open fibro-vascular bundle from a one-year-old twig of *Kerria japonica* (comp. Fig. 350); 200 times enlarged. *h g x* Xylem; *o i n* Phloëm; *h h* Wood fibres; *x* Woody parenchyma; *g* Vessels; *b b* Cambium; *o o n n* Bast parenchyma; *i* Thickened bast-cells; *k* Vascular partition; *g' g''* Other vascular bundles; *m* Pith (the pits are indicated at *t*); *s s* Medullary rays; *r p* Parenchyma cells of the bark, partly filled with chlorophyll; *e* Epidermis (comp. Fig. 352).

go on increasing in thickness *ad libitum.* This central layer of cells constitutes what is termed the *cambium* (*b b*, Fig. 362).

The layers on the outside of the cambium are composed of bast-cells, those on inside of wood-cells, hence the division of the bundle into *bast* or *phloëm*, and *wood* or *xylem*. The bast tissues are indicated in the figure by the letters *o i n*, the wood by the letters *h g x*.

The *cambium* cells always have thin walls, and are entirely filled with protoplasm. The partitions arising by the division of the cambium cells are formed in a tangential direction.

The *wood* or *xylem* layers of the bundle are chiefly composed of prosenchyma cells having lignified walls. Some parenchyma cells are also sometimes present, these being a little modified from the division of the cambium cells.

The two chief elements found in the xylem are true wood cells (fibres) and vessels. The former (*h h x*) constitute the great bulk of this part of the bundle; they are narrow, elongated, and often cylindrical; their walls are much lignified, and contain simple or bordered, round or slit-like pits. They are separated from each other by horizontal or oblique transverse partitions. At the junction of the xylem with the pith, cells are sometimes found intermediate between wood fibres and pith-cells; they are shorter than true wood-cells, are separated by almost horizontal partitions, and are pitted after the manner of pith-cells. The pits of the wood-cells are *open;* the latter being therefore in direct communication, their fluid contents soon disappear, and in the later stages of their existence they contain only air.

The xylem contains a number of *vessels* (*g g*), easily distinguished from the surrounding tissue by their greater diameter. These frequently occur in groups of three or more, lying in a single row, one behind the other, within the layers of wood fibres. They originate from wood-cells by the absorption of the intervening walls, and are distinguished by their size and by the variety of their modes of thickening; they may be spiral, annular, scalariform, reticulated, and pitted (comp. p. 255). Many transition forms are found between true vessels and wood-cells.

The *bast* or *phloëm* lies, as already stated, outside the cambium layer. It consists of two sorts of tissue, *soft bast* and *bast fibres*. Soft bast (*o o*) originally consists of parenchyma cells derived from the cambium, in which latticed cells or *sieve tubes* are

afterwards developed. These are vessels corresponding to the vessels of the xylem, and are produced from rows of bast-cells as the wood vessels are produced from rows of wood-cells. The sieve tubes receive their name from the peculiar manner in which their apposed ends are pitted, these being pierced by numerous holes so as to look like a lattice or sieve. Scattered through the soft bast, or situated at its extreme edge, are groups of much thickened cells, which constitute the *bast fibres* (*i i*).

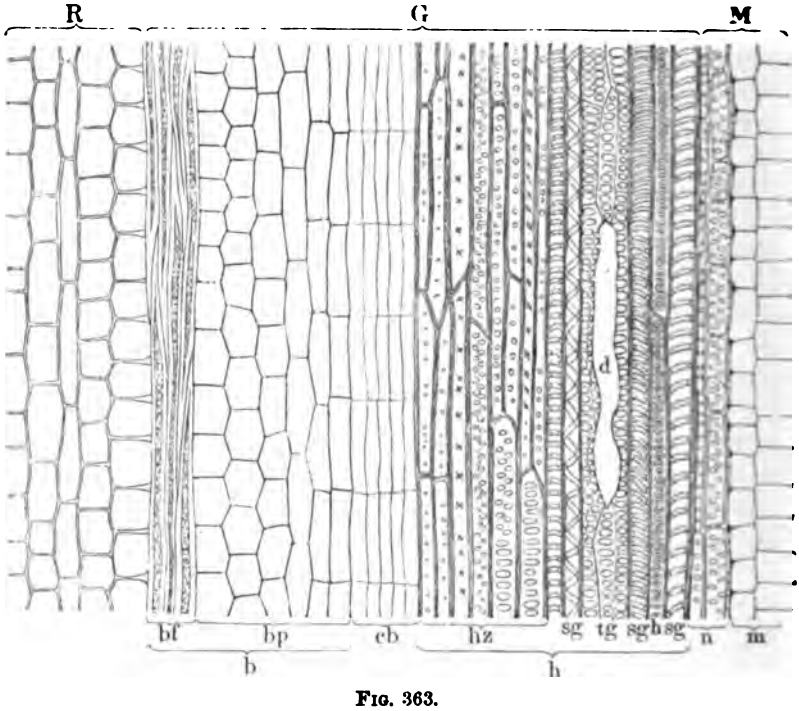


FIG. 363.

Longitudinal section through a vascular bundle from the one-year-old stem of *Corylus tubulosa;* 600 times enlarged. *M* Pith; *G* Vascular bundles; *R* Cortical parenchyma; *m* Thin-walled and *n* Thickened pith cells; *h* Woody part of the vascular bundle; *c b* Cambium; *b* Bast; *sg* Spiral vessels; *tg* Pitted vessels; *hz* Wood fibre cells; *bp* Bast parenchyma; *bf* Thickened bast fibres.

These are developed like wood fibres by the elongation and thickening of cells, and are long, tubular, and pointed at the ends; the individual fibres are thus spindle-shaped. The walls of these cells are very much thickened, but do not contain pits.

Fig. 363 represents a longitudinal section of a fibro-vascular bundle from the young stem of *Corylus tubulosa*. The leading features of the open bundle may here be easily distinguished. *M* indicates a portion of the parenchymatous medulla or pith, *G* the fibro-vascular bundle, *R* the cortical parenchyma; *m* are true, pitted, pith cells, at *n* they have become more woody. The xylem or wood is well seen at *h*, and the phloëm or bast at *b*, the cambium layer occupying the space *c b* between the two. In the wood the following parts may be distinguished: next to the medulla come several vessels,—*sg* spiral, *tg* pitted, the latter being very well marked, and possessing several rows of pits; at *d* the part of the wall of the vessel has been removed. Next to these come numerous wood-cells pitted in various ways; these are distinguished from the vessels by their smaller diameter and by the occurrence of numerous partitions. The soft bast (*bp*) and the bast fibres (*bf*) of the phloëm are sharply marked off. The soft bast seems entirely composed of parenchymatous cells, which vary in length in the different layers, as sieve tubes are not shown in the figure. The characteristic shape of the bast fibres above described is well shown; their granular contents are also indicated.

Beyond the bast fibres are the deeper layers of the cortical parenchyma, the cells of which have slightly thickened walls and contain chlorophyll granules.

The larger fundamental tissue which bounds the vascular bundle is usually different from the rest of the cortical tissue; in most cases it contains numerous starch granules, which are often compound. It is termed the *bundle sheath* (*k*, Fig. 364).

6.—Fundamental Tissue.

Fundamental or ground tissue is a term applicable to all kinds of vegetable tissue, with the exception of the epidermal and the fibro-vascular systems. The term *fundamental parenchyma*, or simply *parenchyma*, is sometimes used as a synonym for fundamental tissue, but the expression is not accurately correct, as fundamental tissue frequently contains prosenchyma cells. The terms, therefore, can only be interchanged when the fundamental tissue consists solely of parenchyma cells.

The fundamental tissue is usually composed of rounded,

elliptical, or cylindrical cells, with thin walls; it contains numerous intercellular spaces (see Fig. 349, p. 277). In those regions lying next to the epidermis, the cell-walls of the fundamental tissue sometimes become thickened, whereby the parts in which they occur become firmer in texture. Collenchyma (comp. p. 246, Fig. 325), and sclerenchyma are examples of tissues composed of such cells. Sclerenchyma consists of much thickened woody parenchyma (Fig. 326, p. 247), and these may frequently lengthen and unite into bands which are not to be confounded with fibro-vascular bundles.

Tissues are also divided into *Protenchyma* and *Epenchyma*. Protenchyma tissues include the primary meristem and the epidermic tissues directly derived from it, with all fibrous structures (*e.g.*, sclerenchyma fibres) which arise from modification of the fundamental tissue. Epenchyma tissues, on the other hand, include all fibro-vascular structures, *i.e.*, all tissues derived from the cambium (comp. p. 290) or procambium (comp. p. 288).

The development of fundamental tissue, apart from collenchyma and sclerenchyma, is tolerably uniform throughout the stem. In many ferns, for example, it forms a thick layer round the central group of fibro-vascular bundles (comp. p. 286), the walls of the cells in the deeper parts being extremely thin, those nearer the surface thicker and brownish. The tissue composed of cells of the former kind is distinguished as the medulla or pith; that composed of the latter, as the cortex or bark; but these are only *different forms* of fundamental tissue.

In the monocotyledons it is seldom possible to draw a sharp line of demarcation between the pith and the cortex. Still, in many monocotyledonous plants (Fig. 349, p. 277), the scattered fibro-vascular bundles (*g*) are all distributed in the central portion of the stem (*m*), and the region *f* may contain a persistent layer of cells still capable of division (meristem, comp. p. 275), while that immediately below the epidermis is traversed only by fibro-vascular bundles passing out to supply the leaves (*g'*). In such cases one may term medulla that portion of the fundamental tissue lying within the layer of meristem, and cortex that lying outside it (*r*).

In the dicotyledons (comp. p. 115) and conifers, on the other hand, the medulla and cortex are sharply distinguished

from each other, the ring of fibro-vascular bundles forming a boundary dividing the one from the other. The ring of fibro-vascular bundles is shown at *g g* in Fig. 350 (p. 277); on the inside is the medulla (*m*), on the outside the cortex (*r*). Between the fibro-vascular bundles are bands of fundamental tissue which connect the medulla with the cortex; these are the *medullary rays* (*s*).

The *medulla* consists of four, five, or many sided parenchyma cells, between which are very small, usually triangular intercellular spaces. Their walls are slightly thickened, and mostly show large, rounded pits (Fig. 363, p. 292). Isolated prosenchyma cells are also occasionally met with in the medulla. The walls of these are much thicker than those of ordinary pith-cells, and are often slightly coloured (*e.g.*, pith of the elder). We have already said that the pith in the vicinity of the fibro-vascular bundles frequently undergoes considerable modification (p. 291). In young plants the stems are very largely composed of pith. As the process of lignification goes on, however, and the fibro-vascular bundles develop, the proportion of pith decreases until in the full-grown stem it finally disappears or becomes confined to a very small area.

The *cellular envelope* (*r p*, Fig. 362) originally consists of regular cubical or prismatic, roundish or cylindrical cells, the shape of which, however, frequently becomes distorted in course of growth (*r*, Fig. 358, p. 285). Their walls are soft and elastic, and as a rule contain no pits. In young stems this layer plays a part in the process of assimilation, and its cells are accordingly filled with chlorophyll grains (comp. p. 261). Like the pith, this layer has to make way for the development of the fibro-vascular bundles, and as the cork (comp. p. 286) forms between it and the peripheral bast layer, it is pushed towards the outside, where, along with the epidermis, most or all of its cells die, and the process of *bark formation* goes on as already described.

The *medullary rays* (*s*, Fig. 362) are represented in young stems by radial layers of cells, separating the fibro-vascular bundles. These differ little in structure and contents from the pith-cells proper. As the fibro-vascular bundles widen, the medullary rays undergo compression, until in the full-grown stem they appear as a system of narrow, radiating, and frequently interrupted lines.

The structure of the medullary rays is illustrated in Fig. 364. The layer of highly lignified pitted cells (*h* in I.) represents the wood; over these are the thin-walled cambium cells (*k*), and beyond these, again, is a portion of the bast (*b*), showing two

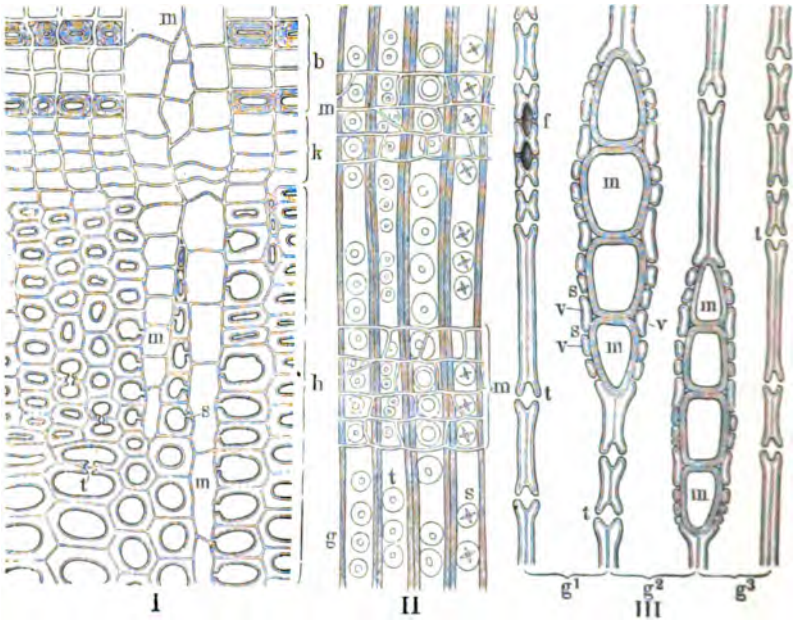


FIG. 364.

I. Transverse, II. Radial, III. Tangential section of the young trunk of *Sequoia gigantea* (giant cyprus), illustrating the medullary rays. *b* Bast, *k* Cambium, *h* Wood, *m* Medullary ray, *t s f* Pits, *g*, g^1, g^2, g^3 Wood fibres, *v* Lignified wall of same. I. and II. 300 times enlarged; III. 1000 times enlarged.

layers in which the bast-cells have been transformed into bast fibres. These tissues all belong to a fibro-vascular bundle, and are cut across by a branching medullary ray (*m*), which is readily distinguished, especially in the wood, by the thinness of its cell-walls. The wood-cells bordering the medullary ray frequently contain closed pits (*s*). In transverse section the cells of the medullary ray are seen to be four-sided, sometimes rectangular. In the radial section (II.), *i.e.*, a longitudinal section cutting entirely along the ray, the relative position of the pith-cells and wood fibres is shown. In the illustration we see two points (*m m*) at which the cells of the medullary ray and the

wood fibres come into communication by means of various sized pits. A third aspect of the medullary rays (*m*) is shown in III., which represents a longitudinal section made perpendicularly (tangentially) to the last,—*i.e.*, cutting across the rays.

In the trunk or stem the fundamental tissue may usually be separated into pith and cortex; in other parts this is not possible. Thus, in the leaves, for example, the fundamental tissue is represented by a tissue termed *mesophyll*, which is uniform throughout, and is composed of more or less regular parenchyma cells containing chlorophyll (Fig. 335, III., p. 262). The carpels, the fruit, the stamens, all manifest special modifications of the fundamental parenchyma. The subject does not admit of any general treatment, and cannot be taken up here.

7.—Tissues of the Root.

Hitherto we have only spoken (pp. 277-297) of such tissues as enter into the composition of the stem or trunk. In the underground axis, the *root*, the arrangement and relative position of fundamental tissue, and fibro-vascular bundles, are, generally speaking, similar. There are, however, certain important distinctions to be drawn, by which root and stem may easily be distinguished.

In longitudinal section the point of a growing root is seen (Fig. 365, I.) to consist of meristem (comp. p. 275), the youngest cells of which (the primary meristem) are situated at *i i*. From this point (the *growing point*) the tissues have become differentiated upwards into the epidermis (*e*), the cortex (*r*), the vascular sheath (*s*), the vascular cylinder (*pl*), and the pith (*m*, II.). Downwards, the primary meristem (*i i*) gives rise to several layers of peculiar parenchymatous cells, which in the earlier stages of growth form a continuous tissue (h^1), but later on (h^2) become less closely connected with each other, and finally wear off one by one. This peculiar structure forms the *root-cap* or *root-sheath*, which serves to protect the growing point from injury as it forces its way downwards. At a later stage many of the cells of the epidermis develop into long hairs, the *root-hairs* (comp. p. 79).

The primary meristem of the root becomes differentiated first of all into three layers, the *dermatogen* (*e*), the *periblem* (*r*), and the *plerome* (*pl*). The first gives rise to the epidermis, the second to the cortical

layer, the third to all those tissues lying within the bundle sheath (*s*), *i.e.*, the vascular bundles. In most roots the bundle sheath (*s* I.) forms a sharp line of demarcation between the periblem (cortex) and the plerome. The modification of the young plerome cells into a vascular

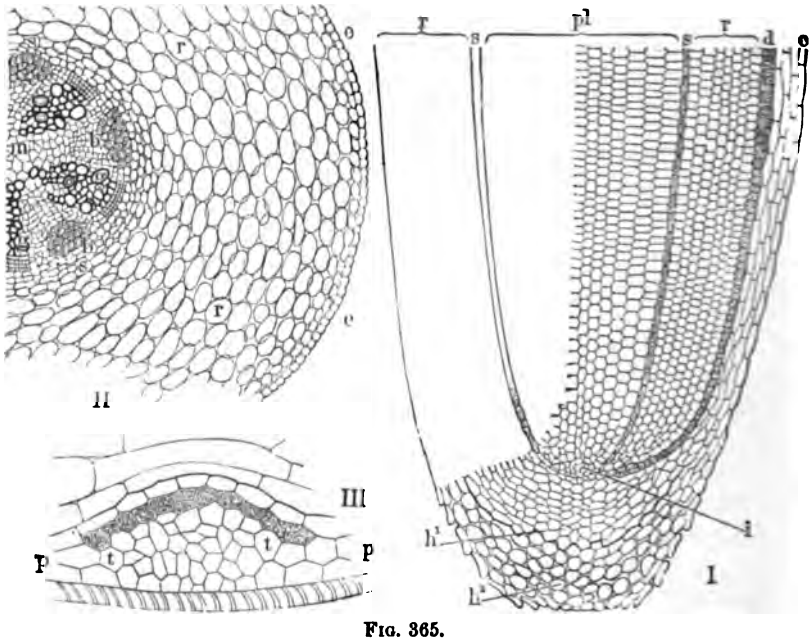


FIG. 365.

Root of Vicia Faba.—I. Longitudinal section of growing point; 200 times enlarged. II. Transverse section across an older part of the root; 100 times enlarged. III. Origin of a secondary root of *Ipomœa*, longitudinal section; 300 times enlarged. *e* Epidermis, *r* Cortex, *s* Bundle sheath, *g* Vascular bundle, *b* Bast, *m* Medulla, *i i* Growing point, h^1 h^2 Root-caps, *pl* Plerome, *p* Pericambium, *t t* Young meristem of secondary root. (III. after Holle).

bundle takes place in the following manner. The process differs from the corresponding process as it takes place in the stem. First, there appear in the peripheral layers of the plerome small groups of vessels, which gradually increase in size, and spread inwards towards the centre of the root. There they finally unite, forming a three, four, five, or more rayed star (*g* II.). Between these groups of vessels patches of soft bast (*b*) are next formed after a similar fashion, so that in the fully developed root we find portions of wood and of bast alternating. In roots which soon cease to increase in thickness, the rest of the plerome becomes transformed into permanent tissue; the plerome cylinder is thus converted into a cylindrical (radial) bundle. In other cases the central portion of the plerome retains its parenchymatous character, and forms a pith. In roots which attain con-

siderable thickness (turnip) a true cambium layer appears, just as in stems, between the xylem and the phloëm portions of the plerome (which in this case lie directly behind each other), and from this layer woody fibres are developed on the one side, bast-fibres on the other.

Secondary roots do not originate from the primary root, as do branches from the stem. They arise from the deeper tissues of the parent organ. Previous to the formation of a secondary root, the cells of the pericambium or outermost layer of the plerome divide repeatedly (*p t*, Fig. 365, III.). The meristem thus formed gives rise to a protuberance on the side of the primary root, and, the epidermis finally giving way, the new rootlet is enabled to push out into the surrounding soil. Fig. 366 represents such a rootlet on the point of breaking through the cortical layer. The cells of the latter are polygonal in shape, small towards the surface (*n*), larger in the deeper layers (*p*). The bundle sheath (*s*) encloses four distinct fibro-vascular bundles (*g*) and the loose pith. The young rootlet (*w*), which is plainly seen to originate from the plerome, is just about to break through the outermost cortical layer.

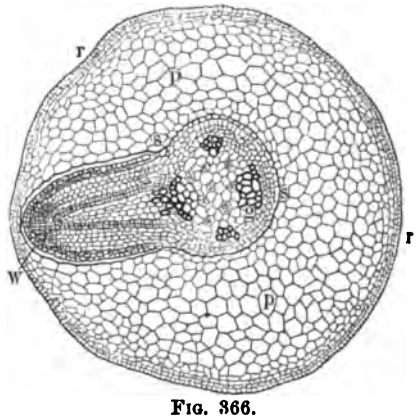


FIG. 366.

Transverse section of a root of a balsam (*Impatiens parviflora*), showing young rootlet (*w*) still enclosed in its tissues. Letters as in Fig. 365. Eighty times enlarged.

8.—ORGANS OF SECRETION.

Under this term are included all structures whose physiological function it is to store up certain materials within themselves, and, as is frequently the case, to discharge these again as necessity requires. These materials are either destined to be of no further use in the economy of the plant, or have to be carried to its surface, there to fulfil new functions. The most important of these organs of secretion are the *laticiferous vessels*, *glands*, *glandular hairs*, and the *canals for the secretion of gum and resin*.

The *laticiferous vessels* are found in all plants which emit "milky juice" when wounded. Such, for example, are the dandelion (*Taraxacum*), the lettuce (*Lactuca virosa*), and the celandine (*Chelidonium*). The milky juice of dandelion and lettuce is white, of celandine yellow. Laticiferous vessels are long and frequently anastomose; they occur in the phloëm, the pith, and the cortex of roots and stems, but not in the xylem.

Glands are small cavities, usually found immediately below the epidermis, which serve as reservoirs for oily or resinous substances. The oil glands in the rind of the orange and citron are familiar. They merely store up the oil, without secreting it on the surface of the fruit. Similar structures for the secretion of gummy or resinous substances are found on the scales of many leaf-buds (comp. p. 17).

Fig. 367 represents an oil gland from the young ovary of *Metrosideros buxifolia*, a myrtaceous plant. It lies below the epidermis, in the fundamental parenchyma, which forms several close layers around it, the cells of which have granular contents. Within the gland is one large and several small yellow oil globules, besides other granular contents.

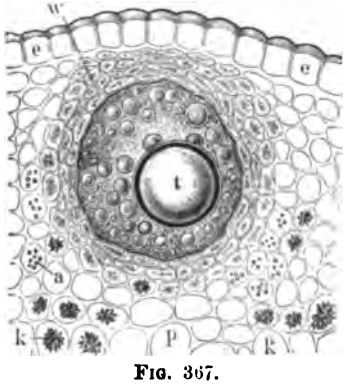


FIG. 367.

Oil gland from the ovary of *Metrosideros buxifolia*; transverse section; 300 times enlarged. *e* Epidermis; *p* Fundamental parenchyma; *w* Inner wall of the gland; *t* Large oil globule; *k* Crystals; *a* Starch granules.

Hairs may also function as glands. Thus the multicellular hairs of the nectary of *Abutilon* (see Fig. 353, p. 280) serve to secrete nectar, which exudes from the uppermost cell. Organs having a viscid surface (*e.g.*, leaves) mostly owe this property to the presence of a fluid secreted by glandular hairs (comp. p. 79).

Finally, *intercellular canals* frequently serve to store up gummy and resinous secretions (comp. Fig. 344, p. 273). Thus in the conifers, especially in the wood, four rows of cells frequently separate to form a passage, into which is secreted a quantity of clear viscid balsam. When exposed to the air, this hardens into the well-known *resin*. The fluid is originally formed in the surrounding wood-cells, and passes into the resin duct by a process of diffusion.

III.—PHYSIOLOGY.

1.—Composition and Nutrition of Plants.

The plant, as will already appear from the foregoing chapters, is composed of organic substances in which the elements oxygen, hydrogen, carbon, and nitrogen preponderate. These, we pointed out, may be broadly divided into carbohydrates and albuminoids; the former are made up of oxygen, hydrogen, and carbon, the latter of the same elements, with nitrogen and a small and variable proportion of sulphur (p. 257). The carbohydrates (cellulose, starch, sugar, inulin) form the solid frame-work of the plant, and those cell-contents which sooner or later go towards the development of the cell-wall. The albuminoids form the protoplasm and chlorophyll grains, *i.e.*, those cell-contents in which are performed the two most important processes of vegetable life, assimilation and respiration. Besides these, there enter into the composition of the plant numerous inorganic substances, such as potassium, sodium, calcium, various phosphates, compounds of ammonia, silicic acid, &c. All these may be regarded as fairly constant constituents in vegetable tissues. Restricted to certain organs or to particular species of plants, there are, however, numerous additional organic substances, such as the alkaloids, which may serve definite ends, or may be regarded as mere excretions.

The young embryo is originally composed of few cells, which multiply by division until the plant attains its full size. The increase in volume thus effected is the result of the assimilation of new matter by the cells. The utilisation of these substances implies the necessity for a supply of new materials to replace those that are used up. These the plant obtains from without.

The nutritive materials on which the plant depends for support are either *fluid* or *gaseous*. Those of the former class consist for the most part of water containing a small quantity of the above-named minerals in solution; they are absorbed by the roots from the surrounding soil. The gaseous nutritive materials are carbonic acid and oxygen; these are absorbed by the aërial parts of the plant (see Stomata, p. 283) from the atmosphere.

The nutritive materials absorbed by the plant are elaborated in its tissues into new substances—undergo transformation. The two processes most intimately connected with this transformation are *respiration* and *assimilation*.

In plants, as in animals, *respiration* consists in the absorption of oxygen and the liberation of carbonic acid. The substances to be oxidised are the carbohydrates and fats which occur in protoplasm, and the non-nitrogenous products of the decomposition of the latter. That the nitrogenous parts of the albuminous substances are not likewise lost by oxidation, is evident from the fact that the sole product of respiration is carbonic acid. It further appears that respiration involves a considerable loss of organic substance, which must be compensated for in the course of assimilation. Assimilation, however, is closely connected with respiration, for it is by the process of oxidation that the chemical equilibrium of the organism is disturbed, and the molecular movement, forming the essential feature of what is called life, generated and maintained. Oxidation is indeed a source of loss to the products of assimilation, but it is at the same time

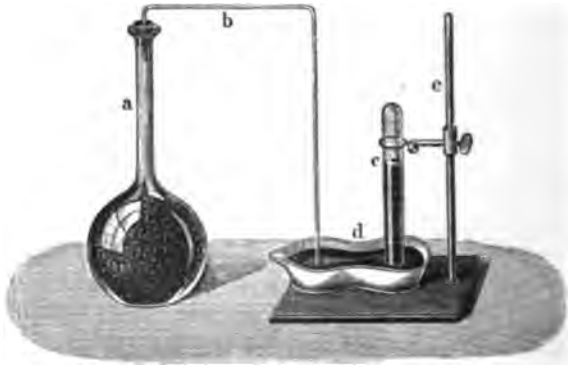


FIG. 368.

Apparatus for demonstrating the liberation of carbonic acid by germinating seeds.

the source whence is derived the energy which renders assimilation possible. We are thus enabled to understand how organs characterised by rapidity of growth (*e.g.*, germinating seeds, flowers) always exhibit great respiratory activity.

The liberation of carbonic acid gas in the process of respiration may be easily demonstrated, especially in such parts as are not coloured green, and accordingly do not assimilate; since in these the process of respiration is not concealed. Fill a Florence flask (Fig. 368, *a*) with moist germinating seeds of the bean (*Vicia Faba*), and connect it with a cylinder containing quicksilver (*c*) by the air-tight tube (*b*). The lower end of the cylinder must be immersed in the quicksilver contained in the vessel *d*. In a short time air-bubbles will be seen to rise in the cylinder and gradually displace the mercury. The explanation is as follows:—The seeds find in the vessel a small quantity of oxygen, and themselves contain in addition a quantity sufficient for the continuance of respiration for some time. Carbonic acid is accordingly given off, passes through and accumulates in the cylinder. Its presence may there easily be detected by the introduction of a piece of caustic lime, which instantaneously enters into chemical combination with the carbonic acid, and forms carbonate of calcium. The gaseous residuum is almost pure nitrogen.

Assimilation is a process essentially different, and even, as far as ultimate results are concerned, absolutely opposed to that of respiration. It consists in the absorption of carbonic acid, and its combination, in the chlorophyll grains, with the elements of water, the results being the formation of carbohydrates and the liberation of oxygen (see p. 282). Whereas the process of respiration is carried on in all parts of the plant, both during the day and during the night, the process of assimilation is confined to the chlorophyll grains, and only takes place under the action of direct or reflected sunlight (see below).

The absorption of fluid substances is effected (water-plants forming a partial exception) by the roots. The water thus absorbed contains various inorganic substances—*e.g.*, acids and salts—in solution; these partly belong to the water itself, partly to the surrounding soil, from which they are extracted by the root-hairs in a manner hitherto unexplained. The water passes into the interior of the plant by a process of diffusion. The constituents of the cell-sap differ in different cells, and the tendency of diffusion is to equalise these differences. When a cell is completely filled with fluid, and, by diffusion through the membrane, water enters that cell, its wall is subjected to a certain amount of pressure. If that pressure be greater than the pressure within the other cells, the first cell swells up, or becomes *turgid*. A tissue is said to be in a state of turgescence when pressure similar to that above described is exerted in all its cells.

All growing parts of plants are turgescent, withered parts are in a state of collapse.

A state of turgescence may be caused in withering shoots by forcing water into their cells. This may be demonstrated by the following experiment:—The end of a drooping shoot (*c* I., Fig. 369) is inserted in a suitably perforated indiarubber stopper. This is fastened into a bent tube (*a*, *b*) filled with water in the manner shown in the cut. The tube being fixed in an upright position by the clip (*e*), a quantity of mercury is poured into it by means of the funnel *d*. The mercury thus occupies the leg *f* (II.), the water the leg *b*. The latter exercises a certain amount of pressure on the water in contact with the cut end of the shoot; this pressure varies according to the difference between the level of the mercury in *f* and the level of the mercury in *g*. The water in *b* is forced into the cells of the shoot, which, in the course of a few seconds, begins to erect itself while its drooping leaves again become turgescent.

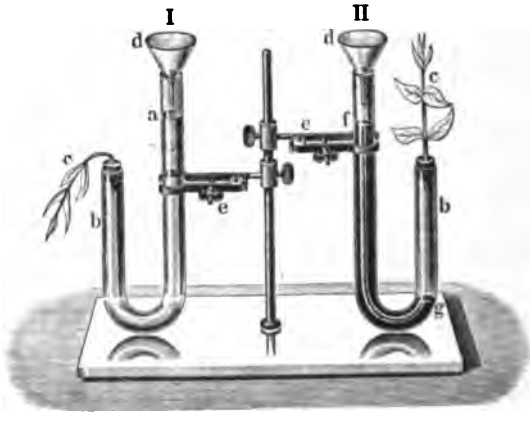


FIG. 369.

Apparatus for showing how withering shoots may be rendered turgescent by artificially forcing water into their cells.

Water passes from one part of the plant to another in the following manner:—One cell, or group of cells, absorbs the water from those in its immediate vicinity; these in turn draw upon deeper layers, and these again on deeper layers still, until at length the roots have to make good the total absorption from the soil. Water is absorbed by all parts of the tissues in the same way.

Besides the water thus taken up for the nutrition and growth of its tissues, the plant has need of a further supply to make up

for the loss effected by *evaporation* or *transpiration*. Most plants have a great extent of surface—*e.g.*, trees, with their countless leaves. Now, the greater the surface the greater the loss of water by evaporation, especially if the atmosphere is dry, and the temperature high, as in strong sunshine. This loss is made up in the same way as that required for growth, except that the transference of the water to the evaporating surface is effected by the xylem portion of the fibro-vascular bundles only.

In both cases, therefore, the water depends for transference on the absorptive powers of the plant, the simplest proof of which lies in the fact that a twig, if cut from the parent plant, will, if placed in water, cover the loss caused by transpiration from its leaves by absorption from the surrounding water, a case in which there can be no question of *pressure* on the tissues. In such circumstances many plants will even continue to grow, the necessary supply of water being likewise obtained by absorption.

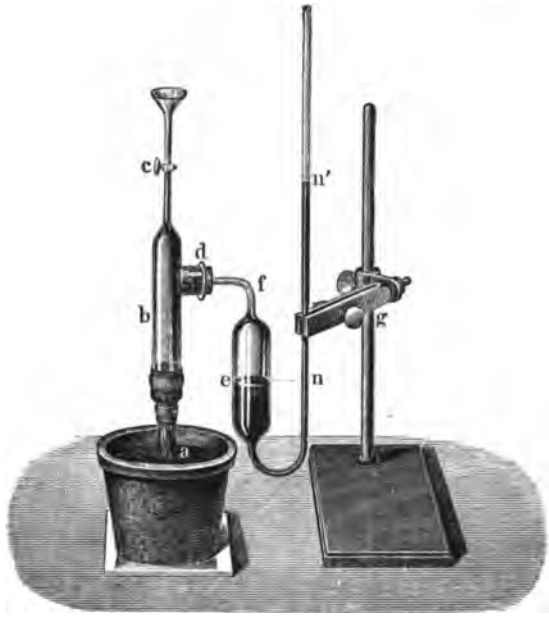


FIG. 370.
Apparatus for demonstrating root-pressure.

Besides the ordinary process of absorption, water is also taken up by the root by the method known as *root-pressure*.

The force of the root-pressure may be demonstrated by cutting across the stem of a young growing plant (*a*, Fig. 370) a little way above the ground, and fastening over it, by means of a piece of indiarubber tubing, a wide glass tube (*b*) provided with a stopcock (*c*). The manometer *f e n'* is then inserted at the opening *d*, and there made fast by means of an indiarubber stopper. The narrow tube of the manometer is supported by the stand *g*. The stopcock *c* being opened, distilled water is poured in through the funnel above, until it fills *n e f d* to above *c*. Mercury is then poured into the tube *n'* till it reaches the level *e* in the wide part of the manometer, a corresponding quantity of water being thereby displaced at *c*. The stopcock is then closed, and the apparatus left to itself for a time. The cut surface of the stem *a* is covered over by the water in *b*, which lies in immediate contact with the mercury of the manometer; if care has been taken, the apparatus should not contain a trace of air. If the soil surrounding the plant *a* is moist, the mercury in the tube *n'* soon begins to rise, and, in the case of many woody plants, continues doing so until the difference between *e* (*n*) and *n'* equals a pressure of half an atmosphere, or a column of mercury about 380 mm. high. In some instances the column of mercury may be as much as 760 mm. high—that is to say, by root-pressure a stream of water is forced up through *a*, capable of displacing a column of mercury many centimetres in height.

Organic matters in solution pass from tissue to tissue in the same way as water. The carbohydrates—starch, for example—leave the cells in which they are stored, as a soluble substance (*dextrose*), and pass to other parts, where they are utilised in the formation of new tissues. On the other hand, the starch elaborated in the chlorophyll grains of woody plants in early autumn leaves the green parts, and passes through the parenchyma cells of the cortex to the medullary rays (p. 295) of the trunk, where it is stored up over the winter in permanent form. As soon as the period of growth returns, it again becomes soluble, and passes out as dextrose to the developing buds. The proteid substances from the leaves appear to pass inwards through the soft bast.

2.—Growth and its Conditions.

By growth is meant increase of volume arising from an internal cause, the formation and enlargement of the cells constituting the various tissues of the plant. As a rule, growth depends both on internal and external conditions. Of internal conditions we have already had abundant examples in such processes as those already considered, upon the normal

and harmonious working of which the further development of the plant depends. The internal processes of the vegetable organism are maintained and regulated in accordance with certain external circumstances. Granted that the plant is so developed as to be capable of performing the functions of respiration and assimilation, the extent to which these functions are carried on depends on the influence exercised by *temperature, light, gravitation,* and other local external circumstances.

(1.) *Temperature.*—The influence of *temperature* is one of very great importance to the plant; it can never rise above a certain maximum, nor fall below a certain minimum, without its rise or fall being followed by the most injurious results. Vegetable life cannot be maintained at a temperature above 50° C. on the one hand, or below 0° C. on the other. The mean temperature differs of course for each plant, or at least for the plants of different climates; in general, it corresponds to the mean annual temperature of the plant's habitat.

To cite a few examples, the young root of the maize attains its maximum rate of growth at 27·2° C., that of the pea, wheat, and barley at 22·8° C. If the temperature falls below this optimum growth is immediately checked, continued exposure to the same degree of cold finally resulting in the death of the plant. In like manner subjection to a temperature much above the optimum results in almost immediate death. The death of plants from exposure to too low or too high a temperature depends essentially on the amount of moisture they contain. Dry seeds, for example, can stand a much higher or much lower temperature than soft fleshy ones, the former, it would appear, even being capable of bearing the most extreme degrees of cold without injury. Thus dried peas are capable of standing a temperature of + 70° C. for over an hour without losing their power of germination, whereas the same seeds, if made soft by soaking in water, become useless if subjected for a like length of time to a temperature of 54°-55° C.

The *periodic growth* characteristic of our perennial plants is the result of periodic differences in temperature. In them growth is most rapid in spring, diminishes gradually as summer advances, reaches a minimum in autumn, and in winter ceases altogether. This periodic growth is marked by the formation of *annual rings.* These arise from the fact that in the woody part of the fibro-vascular bundles the wood-cells formed in spring (*f,* Fig. 371) are larger than those formed in autumn

(*h*). A sharp line of demarcation is thus formed, dividing the cells of one year from those of the one preceding.

(2.) *Light.*—Apart from the thermal effects above referred to—which are always more or less combined with those of light—light influences plants with either *chemical* or *mechanical* results. The chemical effects of light are to decompose, modify, or cause to enter into combination certain substances found in vegetable tissues; for instance, as in photography, chloride of silver is decomposed by its influence.

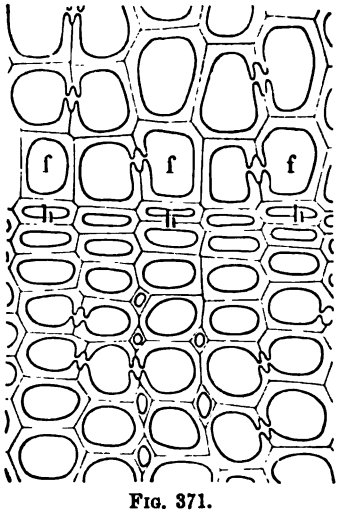


FIG. 371.

Formation of the annual ring in a three-year-old pine trunk (*Pinus silvestris*).—*f f* Wood-cells formed in spring; *h h* The same formed in autumn; 600 times enlarged.

This *chemical* action causes the *assimilation of carbonic acid*, and accordingly the production and destruction of chlorophyll. Assimilation, *i.e.*, the union of carbonic acid and water so as to form a new organic compound, is *exclusively* dependent on light. Plants do not assimilate in darkness, but only under the influence of light, particularly of direct sunlight. The more intense the sunlight the more actively does assimilation go on; the process is mostly effected by means of the *yellow rays*.

Chlorophyll is elaborated from a yellow colouring matter, *etiolin*. Plants grown in the dark are not green, but yellow; they contain only etiolin, no chlorophyll. Plants in this condition are said to be *etiolated*. If an etiolated plant be exposed to daylight or direct sunlight it will become green—very rapidly in the latter case. Under the action of light the etiolin has been transferred into chlorophyll, and the process of assimilation can now for the first time take place. The green colour is developed most rapidly in the strongest light rays (yellow to orange). Respiration increases with the intensity of the light, but the chlorophyll having the power of absorbing the strongest rays, the activity of the process of respiration is concealed by that of assimilation.

The destruction of chlorophyll by light is not a normal but an abnormal occurrence.

The most important *mechanical* effect of light on plants may be very briefly explained. Upon the growth of all parts of the plant appearing above-ground (stem, leaves) light exercises a retarding influence; the growth of aërial roots, and in many cases of subterranean roots likewise, is also in a great degree affected by light. When only one side of a stalk is exposed to sunlight, growth takes place more actively in that side of the stalk which is turned *from* the light, than in that which is turned *towards* it; the stalk is therefore bent towards the light, showing *positive heliotropism.* In roots, on the other hand, growth is most rapid on the side next the light; roots therefore are bent *from* the light, showing *negative heliotropism.*

Every one is familiar with the phenomenon of plants bending towards the light, when light reaches them only from one side. A seedling pea, for example, if placed in a window, soon begins to bend over towards it. The side of the stem turned to the window receives a larger share of sunlight than the other, and accordingly grows more slowly; the curvature of the stem is the result of this inequality of growth. The movements of the leaves of many plants are to be attributed to the fact that the light exerts a stimulus at certain points, whereby the tension of these parts is altered, and the tension of the whole tissue accordingly becomes unequal.

To sum up generally the effects produced on assimilation and growth by light—by day assimilation proceeds rapidly, growth is feeble; by night growth proceeds rapidly, assimilation ceases.

(3.) *Gravity.*—It is a well-known fact that the stem of the plant grows perpendicularly upwards, the root downwards in an opposite direction. The long axis of the plant, if prolonged, would pass through the centre of the earth. This is due to the influence of gravitation on the growing parts. If a seedling pea, when about 10 cm. long, is laid along the ground in a horizontal position, the parts already grown will retain this direction, but the growing tip of the root will push downwards, the growing tip of the stem upwards. The tendency manifested by the root to grow towards the centre of the earth is termed *geotropism.* The root is *positively,* the stem *negatively geotropic.*

The following experiment serves to demonstrate the influence of gravity on the growing root and stem. Let a seedling pea, roots included, be placed in a horizontal position in a glass vessel contain-

ing enough moisture to keep the plant alive under ordinary circumstances for some time. The vessel must then be attached to the circumference of a horizontal disk, kept constantly rotating at a rapid rate, in such a manner that the long axis of the plant will lie in the direction of the tangent. If the disk be kept rotating at a sufficiently rapid rate, the root tip will grow outwards, the stem tip inwards (*i.e.*, towards the centre), in the direction of one of the radii of the disk. The experiment may be still more successfully performed if the disk is placed in a vertical instead of a horizontal position, so as to imitate more closely the ordinary conditions of gravitation; the tip of the stem then grows straight towards the centre of rotation, the root in the opposite direction.

PART V.

THE LOWER PLANTS.

It is not the object of the following pages to make an exhaustive examination of the peculiarities of the lower forms of plant life, but only to treat of them so far as is necessary satisfactorily to complete a general survey of the vegetable kingdom. We shall therefore deal more particularly with such groups as serve to show the connection between one form and another, while others, of less importance in this respect, will either be treated of very shortly, or entirely omitted. Within the last few decades, science has made such rapid strides in this department, and such a quantity of interesting materials has been amassed, that it would be altogether beyond the scope of a text-book like the present to attempt to discuss the subject fully. The microscope has revealed to us a world of minute organisms, wherein we may contemplate every stage of life from that of the undifferentiated mass of protoplasm upwards through organisms of all degrees of complexity of structure. To research of this kind it is that we owe our present knowledge of the complicated processes of life as carried on in the highest vegetable organisms. Especially is this the case with regard to the subject of *sexual reproduction.* Whereas in the higher plants this process is universally carried on in the same manner (comp. pp. 162-177), in the lower plants it assumes many different forms. By comparative researches, pursued on a more or less extensive scale during the last twenty or thirty years in connection with the subject of reproduction, more particularly of reproduction as it occurs among the lower species of plants, it is now possible to trace the life-history of the most complicated organism in the progress of its development from the single cell.

The following table is intended to give a general view of the leading vegetable types, with two of which, the monocotyledons and dicotyledons (pp. 101-161), we are already familiar.

General Survey of the leading Types of the Vegetable Kingdom.

I. Reproduction by unicellular spores, without embryo and cotyledons; in every case without flowers. *Cryptogamia.*

A. Vegetative body composed solely of parenchyma cells (without vascular bundles); not divided into stem and leaves, but homogeneous (*Thallus*). *Cellular plants, Thallophytes.*

a. Sexual organs mostly wanting; reproduction proceeding by division, budding, or spore-formation. Mostly single-celled organisms, — 1. PROTOPHYTES.

b. Sexual organs usually present, represented by two locally separated cells.

* Without chlorophyll, therefore not coloured green, very seldom living in water; body consisting of *hyphæ*, ... — 2. FUNGI.

* * With chlorophyll, or with yellow, brown, or red colouring matter allied to chlorophyll, almost all living in water; not consisting of hyphal tissue, ... — 3. ALGÆ.

B. Body consisting of parenchyma tissue and vascular bundles (the latter occasionally very simple), almost always possessing differentiated stems and leaves.

a. Vascular bundles imperfect, vessels undeveloped. Reproduction proceeds by antheridia and archegonia. The fertilised embryonic cell in the archegonium develops into a capsule (sporogonium) containing the spores. (*Muscineæ.*)

* Capsule without calyptra, dehiscence by valves, without columella, without hood; producing spores (mostly accompanied by elaters). Plant either a thallus, or having differentiated stem and leaves, . . — 4. LIVERWORTS.

* * Capsule dehiscing by a lid, columella present, producing only spores. Differentiated into stems and leaves, . . . — 5. MOSSES.

b. Vascular bundles (also epidermis) well developed, the former with developed vessels. Reproduction carried on by antheridia and archegonia, growing on a thallus-shaped body, the *prothallium*. The fertilised embryonic cell in the archegonium develops into a larger body (sporophore), bearing leaves to

which the sporangia or capsules containing the spores are attached. *Vascular Cryptogams* (*Ferns, &c.*).

* The sporangia are attached to the edge or to the under side of the frond (frequently metamorphosed), and produce only one kind of spore. Fronds always leaf-like, . 6. FERNS.

* * The sporangia are arranged so as to form a spike at the apex of the stem, and produce only one kind of spore. Stem composed of a number of cylindrical or angular joints, ... 7. HORSETAILS.

* * * The sporangia are arranged so as to form capsular structures in the vicinity of the root, or are there concealed within a frond. They produce two kinds of spores, . 8. RHIZOCARPS.

* * * * The sporangia are situated at the base or in the axils of small, ill-developed leaves; the latter are often arranged so as to form a kind of spike at the apex of the shoot; they produce two kinds of spores, . . . 9. CLUBMOSSES.

II. Reproduction by means of multicellular *seeds*, which contain an *embryo* consisting of radicle, plumule, and cotyledons: the seeds are produced in flowers after previous fertilisation by pollen. *Phanerogamia.*

A. Flowers without floral envelopes. Seed not enclosed in an ovary. *Archisperms*, . . 10. CONIFERS.

B. Flowers with single or double envelope (seldom suppressed) and true ovary. *Metasperms.*

a. With one cotyledon; vascular bundles scattered, closed; venation parallel; flowers three, rarely four, parted, ... 11. MONOCOTYLEDONS.

b. With two cotyledons; vascular bundles arranged concentrically, open; venation reticulated; flowers mostly five or four parted, . . 12. DICOTYLEDONS.

A. CRYPTOGAMS, OR FLOWERLESS PLANTS.

In the cryptogams or flowerless plants reproduction takes place by means of *spores*. A spore is a minute, mostly microscopic, cell, surrounded by a single or double envelope, and filled with protoplasm. Except in the case of the Protophyta, the spore is the product of sexual conjugation, and is either directly originated by that act, or, as mostly happens, is borne on a fructification (often of considerable size) formed from the

fertilised female cell (embryonic cell). Spores are entirely destitute of an embryo (comp. p. 78) having plumule, radicle, and cotyledons. Plants in which reproduction takes place by means of spores never bear flowers, in the ordinary sense of that term. They either consist entirely of parenchyma tissue, or of fundamental tissue and fibro-vascular bundles; in the latter case the fibro-vascular bundles generally occupy the centre of the stem.

First Series.

THALLOPHYTES, OR CELLULAR PLANTS.

The Thallophytes are distinguished by the entire absence of vascular bundles. The vegetative body consists either of a single cell, or is made up of several or many cells. If multicellular the plant is composed of uniform or tolerably uniform parenchymatous tissue; highly differentiated systems of tissues, such as are met with among the higher plants (comp. p. 277), are never present. This simple form of vegetable structure is known as a *thallus*. Reproduction is effected by very different means in different types; it may take place *asexually* (by division or by budding) or *sexually*. In the latter case the two sexual organs (♂ and ♀) are represented each by a single cell, the contents of which become wholly or partially blended.

Formerly the Thallophytes were divided into *Algæ*, *Fungi*, and *Lichens*, but recent discoveries have shown this division to be no longer tenable. Lichens are now known not to be independent organisms, but are a union of two different forms of vegetation, Algæ and Fungi. The latter are parasitic on the former, and so closely is the life of the one bound up in that of the other, that we cannot wonder at their being for long regarded as a distinct class of plants. Fungi and Algæ may be best distinguished from each other by the absence or presence of chlorophyll; all cellular plants containing chlorophyll are Algæ, all without chlorophyll are Fungi. The Algæ are accordingly plants capable of independently assimilating like the higher plants, while Fungi, with few exceptions, live on substances already assimilated.

Type I.

PROTOPHYTA.

The Protophyta are the simplest of all vegetable organisms. They are mostly unicellular, but when reproduction takes place

by means of cell-division, the daughter-cells frequently remain united and form filaments, tissues, or masses. Except possibly in the Myxomycetes, sexual organs have not as yet been discovered in the Protophyta; reproduction takes place either by simple cell-division, by budding, or by spores. Certain forms of the Protophyta possess chlorophyll, and are accordingly sometimes classed as Algæ; others are destitute of chlorophyll, and correspond more to the fungi. The former are unimportant; of the latter we shall mention three orders:—

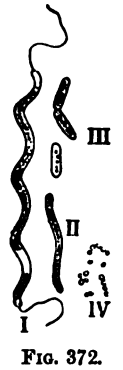


FIG. 372.

Bacteria.—I. *Spirillum volutans* (Ehrenberg); II. *Vibrio Rugula* (Müll); III. *Bacterium Lineola* (Cohn); IV. *Micrococcus prodigiosus* (Cohn); 650 times enlarged. (After Cohn.)

(1.) *Schizomycetes or Bacteria.*—Minute unicellular organisms of globular (Fig. 372, IV.), rod-like (II.-III.), or filiform shape, sometimes ciliated (comp. p. 269). They are usually unicellular, but multiply by division, after which the young cells frequently remain attached, and form colonies (Fig. 373).

Bacteria live in stagnant and putrid fluids, also in diseased animal organs. They always appear in large numbers. According to the effects produced by these organisms in the substance in which they live, they are divided into *pigment*, *ferment*, and *pathogenous bacteria*. The first, when exposed to air, impart to the surrounding fluid particular colours (red milk); the second give rise to fermentation (see below), even when the oxygen of the atmosphere is excluded; the pathogenous bacteria accompany or cause infectious diseases, such as diphtheria, typhus, phthisis, smallpox, and splenic fever. GENERA—*Micrococcus*, *Bacterium*, *Bacillus*, *Sarcina*, *Beggiatoa*, *Spirillum*, *&c.*

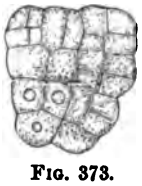


FIG. 373.

Sarcina ventriculi (Goodsir). A bacterial organism from the vomit of a dyspeptic patient.

(2.) *Saccharomycetes or Yeast Fungi.*—These are likewise unicellular organisms, of roundish, elliptical, or elongated shape (Fig. 374). Reproduction takes place by budding, and by internal division. The process of reproduction by budding is as follows:—At one end of the yeast-cell a bud (III. *a*), more rarely two (IV. *a b*), is formed, which gradually increases in size, and is finally separated from the parent cell by a transverse partition. The same process is then repeated in the bud.

The buds frequently remain attached to each other and form colonies. When reproduction takes place by internal division the contents of the parent cell divide into two, three, or four portions, each of which assumes a rounded form and develops a cell-wall. When the wall of the parent cell finally gives way each segment develops into a new yeast plant, which multiplies by budding. Budding is the result of a superabundance of nutritive material, the latter process of the lack of it.

Yeast fungi are the cause of alcoholic fermentation. The beer fungus is *Saccharomyces cerevisiæ* (Fig. 374, I.-IV.); that of wine, *S. ellipsoideus* (also *S. apiculatus* and *S. Pasteurianus*). In fermentation the sugar of the nutritive fluid is transformed by the fungi into alcohol, carbonic acid gas being set free during the process. Chemists are disagreed as to whether or not fermentation takes place only when free oxygen is present.

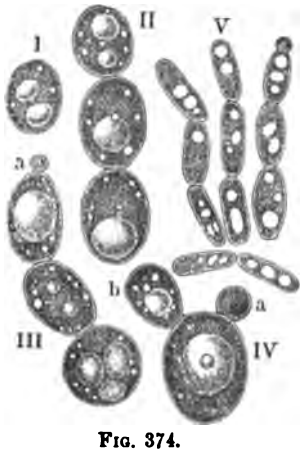


FIG. 374.

YEAST FUNGI. — I.-IV. Beer fungi (*Saccharomyces cerevisiæ*, Meyen), showing the process of budding. V. *Saccharomyces Mycoderma* (Rees), 1000 times enlarged.

Another species of yeast plant, *Saccharomyces Mycoderma* (Fig. 374, V.), is not an ordinary ferment, but a true mould. It grows on the surface of stale wine or beer, and, in contact with atmospheric oxygen, transforms the alcohol of these liquors into vinegar. To this class also belongs *Saccharomyces albicans*, which causes the disease known as thrush. The saccharomycetes were formerly regarded as degenerate forms of higher plants; it now seems probable, however, that they are really independent organisms.

(3.) *Myxomycetes or Mycetozoa.*—The mature organism forms a large fungus-like body, the sporangium, in which are produced numerous spores. In the process of germination the contents of each spore pass out, and exist for some time as a naked mass of protoplasm, containing vacuoles, and exhibiting amœboid movements. It is possessed of the power of locomotion, can push out pseudopodia from any part, and in all respects closely

resembles an Amœba. In this stage the organism is known as a *myxamœba*. Later on, a number of myxamœbæ unite to form a large slimy mass (*plasmodium*), which moves about in the same manner as a single myxamœba. Finally, the plasmodium becomes hardened, and forms *sporangia*, in which the spores are formed; these are of considerable size.

The myxomycetes live on decaying vegetation in woods, hothouses, &c. A common species is *Æthalium septicum*, the plasmodia of which frequently attain a considerable size.

Type II.

FUNGI.

The thallus of fungi is composed of filiform branching threads or *hyphæ*, densely interwoven with one another into a body termed the *mycelium*. The hyphæ contain neither chlorophyll nor starch. Fungi, accordingly, cannot assimilate, but absorb organic matter from the substances on which they live; they are therefore parasitic. The mycelium is usually subterranean, or is hidden in the tissues of the plant on which the fungus feeds. The part commonly considered the whole fungus is in reality the fructification which arises from the mycelium, and appears above the surface of the soil. Fig. 375, I., represents the fructification of the mushroom. At the lower end are numerous fibrous threads (*m*), part of the mycelium taken from the soil and washed clean.

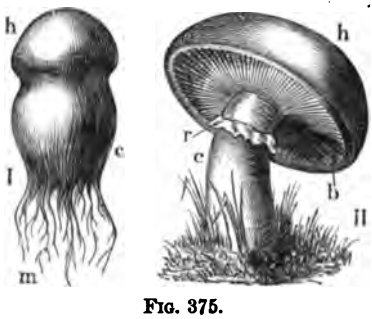


FIG. 375.

Agaricus campestris (mushroom). — I. Young fructification, with mycelium (*m*). II. Fructification almost mature; *c* Stalk; *r* Ring; *h* Pileus; *b* Gills; nat. size.

In fungi reproduction takes place sexually and asexually; it is probable, indeed, that sexual propagation occurs in all forms of fungi, but in many it has not as yet been clearly made out.

Sexual propagation is effected by means of two cells, which are of different sex—a *germ-cell* (♀), and a *sperm-cell* (♂). The latter generally produces *spermatozoids* (see below), which penetrate the germ-cell where the contents of the two mingle, and the process

of fertilisation is complete (comp. p. 168). The product is either an *oōspore*, which either develops directly into a new plant, or sometimes first produces swarm-spores (*Saprolegniaceæ, Peronosporeæ*), or it is an imperfect or a perfect fructification (*receptacle*), which bears the spores.

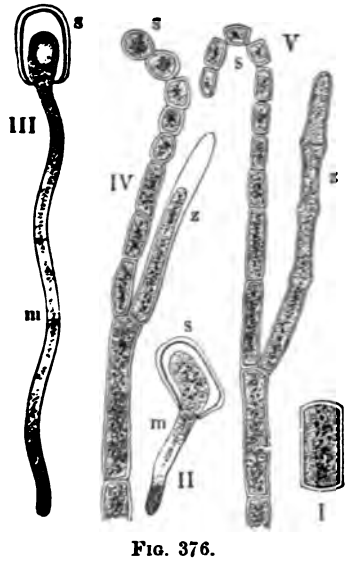


FIG. 376.

Oidium lactis.—I. II. III. Germinating spores in glycerine. IV. V. Branches, with chain of conidia at the end ; 600 times enlarged.

Another mode of reproduction, very common in certain *Ascomycetes*, is that which is effected by the formation of *conidia*. This mode is purely vegetative, not sexual.

Reproduction by the formation of these bud-spores or *conidia* takes place as follows :—The mycelium or vegetative body of the fungus gives off upright branches (IV. V., Fig. 376). The tips of the branches thus formed, each bud off a chain of cells (*s, conidia*), which fall off one by one (I.). Under favourable conditions these germinate and form new mycelia, the cell-wall giving way so as to make way for the protrusion of the delicate hypha (*m*, II. III.).

Fungi are found in the most diverse situations. Many grow on the soil (of forests, &c.), from which they absorb decaying organic matter. Others form their mycelium in the trunks of living trees (Fig. 377), and many, especially the smaller forms, live on leaves, fruits, and other vegetable organs. Certain fungi live on human and animal tissues,—*e.g.*, *Cordiceps* is parasitic on the larvæ of insects, *Botrytis Bassiana* on the silk-worm, causing the muscardine disease ; *Achorion Schœnleinii* is found on the roots of human hair, causing a yellow scurf. Many species live on and in decaying substances,—some even are parasitic upon other fungi (*Chætocladium Jonesii* absorbs its nourishment from the filaments of a mould).

FIG. 377.

(*a*) *Peziza virginea* on a dry beech twig ; nat. size.

Many fungi are characterised by what is termed *alternation of generations*, a subject of which we shall have more to say later.

Orders of Fungi.

I. Hyphæ of the mycelium delicate, mostly unicellular, and not divided by transverse partitions. Sexual cells homogeneous or heterogeneous; sexual product an oöspore, 1. PHYCOMYCETES.

II. Hyphæ stronger, multicellular, divided by transverse partitions. Sexual cells heterogeneous. Sexual product generated on a fructification or receptacle.

A. Spores formed by the ends of the mycelial threads arranged in a chain, and indefinite in number, ... 2. HYPODERMIÆ.

B. Spores different from the foregoing.

1. Spores usually eight in number, contained in a mother-cell (*ascus*), 3. ASCOMYCETES.

2. Spores borne in groups of four (rarely two) at the end of a club-shaped cell (*basidium*), ... 4. BASIDIOMYCETES.

(1.) *Phycomycetes.*—Small, mostly mould-like fungi, with a peculiar mode of reproduction. The two sexual cells either (1.) by conjugation generate a *zygospore* directly capable of germination, and arising by the cutting off of a portion of each cell, and the blending of the contents of the two segments thus formed, or (2.) the globular germ-cell is penetrated by a tubular process of the spermatic cell, and so fertilised (*Peronosporeæ*).

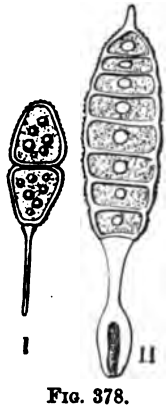


FIG. 378.

Winter-spores of Uredineæ. I. *Puccinia Anemones.* II. *Phragmidium Rosæ;* 300 times enlarged.

To this class belong the *Saprolegniaceæ* and *Peronosporeæ*. The former are parasitic on animals, the latter on plants. *Peronospora infestans*, the potato fungus, causes the well-known potato disease. It forms on the under surface of the potato leaves, and has the appearance of a fine mould. Its colourless filaments (the mycelium) penetrate the tissues of the leaf, which withers all round the parts affected. It thus gets dotted over with small brown specks, which increase in size and number, until finally the whole plant loses its green colour and dies. The numerous spores generated by the fungus are carried by the wind to sound potato plants, which thus become infected. The mycelium lodges over the winter in the tubers, and may thus spring up on the plants of the following year. No effectual means have yet been discovered

for stamping out this troublesome fungus. Potato disease first appeared in Germany in 1830, and in 1845 made terrible havoc. Since then its ravages have been considerably lessened.

(2.) *Hypodermiæ.*—The spores are formed by constriction at the end of the mycelium filament. Nuclei appear equal in number to the spores to be produced, after which definite walls are formed, and the spores thus generated assume a rounded form, and fall off. All fungi of this class are parasites, the mycelia of which often grow for years on the same plant; they are the cause of most of the diseases to which plants are subject. Two families.

(1.) USTILAGINEÆ.—*Tilletia caries* ("smut" of wheat), *Ustilago Carbo* ("smut" of oats and barley), *Polycystis occulta* (parasitic on rye-straw).

(2.) UREDINEÆ.—The Uredineæ are commonly found close under the epidermis of living leaves and stems. Their method of reproduction is characterised by what is known as *alternation of generations.* The first or vegetative generation produces two kinds of spores,—summer-spores (*Uredospores*) and winter-spores (*Teleutospores*, Fig. 378). The former germinate immediately after their appearance, the latter are formed in autumn, and last over the winter. On the pro-mycelium of the teleutospores conidia become developed; these germinate into an extensive mycelium, the *Æcidium* stage. On this (probably sexually) chains of *æcidiospores* are formed, which germinate (usually on another host), ultimately becoming uredospores and teleutospores. The various stages of development were formerly taken for different species of fungi.

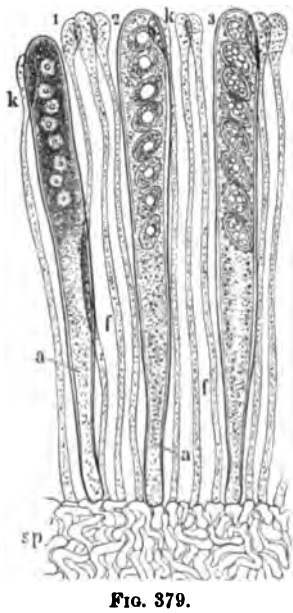


FIG. 379.

Formation of spores in the asci of *Peziza aurantium*; 600 times enlarged. For explanation see text.

To this class belong the familiar *Corn Mildew* (*Puccinia graminis*), the Æcidium form of which (*Æcidium berberidis*) is parasitic on the leaves of the barberry, *Rœstelia cancellata* (Teleutospores found on *Juniperus*, Æcidia on the leaves of the pear-tree), *Phragmidium* (found on rose and blackberry leaves, &c.), *Endophyllum sempervivi* (on the leaves of *Sempervivum*).

(3.) *Ascomycetes.*—The Ascomycetes form their spores in

special mother-cells (*asci*), which grow together in numbers, and form a hymenium. Between the asci are unicellular or multicellular hairs (*paraphyses*, *k*, Fig. 379).

In Fig. 379 we have the asci of *Peziza aurantium*. The lower part of the figure (*sp*) represents a small portion of the hymenium. Arising from this are a number of thickened filaments (*k*), filled with red granules (paraphyses, *f*); between these are three asci (*a*) showing the spores in various stages of development. The ascus 1 contains only protoplasm, in which are eight nuclei, developed by continued division from a single primary nucleus. The protoplasm is almost entirely concentrated at the top of the ascus, that remaining in the lower part only forming a thin coating on the inner wall. The nuclei soon arrange themselves in regular order (see Fig. 379), and become surrounded each by a portion of clear protoplasm, and enclosed by a membrane (see free cell-formation, p. 269). The membrane continues to increase in thickness, and forms at length the wall of the spore. Later on the spores are liberated by the rupture of the wall of the ascus.

Families of Ascomycetes.

I. Asci naked, not enclosed within the receptacle, 1. GYMNOASCI.

II. Asci enclosed.

A. Without firm hymenium. Mould-like fungi, 2. ERYSIPHEI.

B. With firm hymenium.

a. Receptacle a fungus-like body, opening by a pore, ... 3. PYRENOMYCETES.

b. Receptacle not opening by a pore.

* Hymenium situated on the receptacle, which appears above the soil, . 4. DISCOMYCETES.

** Hymenium formed on winding passages in the interior of an underground fructification or receptacle, 5. TUBERACEI.

1. GYMNOASCI.—*Protomyces* (in vegetable stems), *Gymnoascus* (on horse dung). 2. ERISYPHEI.—*Erysiphe*, the conidia form of one species of which, *Oïdium Tuckeri*, forms the well-known vine disease; *Eurotium* [the conidia-bearing form constitutes the common "mould" (*Aspergillus glaucus*)]. 3. PYRENOMYCETES.—*Sphæria*, on dry stems, &c.; *Fumago; Ustulina deusta*, at the foot of old tree trunks—when old has the appearance of charcoal; *Xylaria Hypoxylon*, in rotting tree trunks; *Claviceps purpurea*, the fungus, constituting the *ergot* of rye. 4. DISCOMYCETES.—*Peziza* (Fig. 377), small or large fungi (sometimes 10 cm. in diameter), growing on the ground or on the branches of trees; receptacle (*a*), cup or disk-shaped, the hollowed inner surface entirely occupied by asci and paraphyses (Fig. 379); *Morchella* (about ten species are found in Germany) and *Helvella*.

5. TUBERACEI.—The truffle (*Tuber*), *Elaphomyces*, and *Penicillium glaucum*, the conidia-bearing form of which is the commonest mould on bread, cheese, &c.

Appendix to the Ascomycetes.

LICHENS.

The lichens form a division of plants, comprising several thousand species, which are distinguished, according to the form they assume, as crustaceous, foliaceous, cup-shaped, fruticose, &c. (see Figs. 380, 381, 382); they grow on trees, stones, the earth, and elsewhere. Of late years many interesting discoveries have been made in regard to these plants, which seem

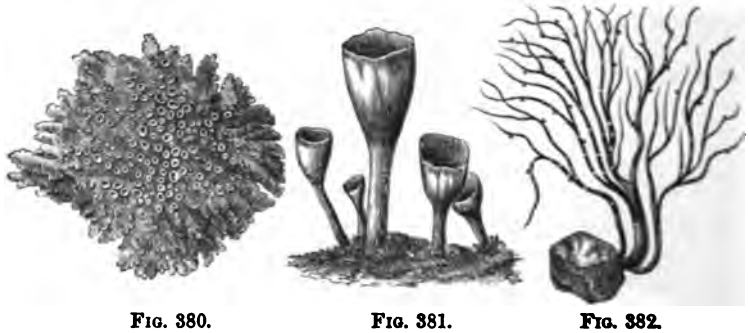


FIG. 380. FIG. 381. FIG. 382.

LICHENS.—Fig. 380.—Foliaceous, *Physcia pulverulenta*. Fig. 381.—Cup-shaped, *Cladonia pyxidata*. Fig. 382.—Fruticose, a species of *Roccella* (perhaps new) from Spitzbergen; nat. size.

to stand alone in the vegetable world. They are not, as was formerly supposed, independent organisms, but are produced by the union (*symbiosis*, De Bary) of two thallophytes, one of which (the alga) contains chlorophyll, and forms a substratum for the other (the fungus), which contains no chlorophyll. In other words, lichens originate by certain fungi living as parasites on certain algæ (mostly unicellular), such as *Nostoc*, *Pleurococcus*, &c. The mycelia of different species of fungi living on different species of Algæ give rise to peculiar forms of lichens. It has long been known that the lichen thallus is made up of two elements, a closely interwoven tissue of colourless fungus filaments (hyphæ), in the interstices of which are numerous rounded, bright green cells ("gonidia"). The filaments constitute the fungal element, the gonidia the algal element, of

the organism. The lichen thallus is also capable of producing certain cup-like structures (fructifications, Fig. 380), in which are developed numerous asci, supported on filaments. The spores are formed in the same manner as those of *Peziza* (see p. 320). In respect of the processes by which multiplication takes place, the lichens in many points resemble the Ascomycetes, and accordingly must be classified very near them.

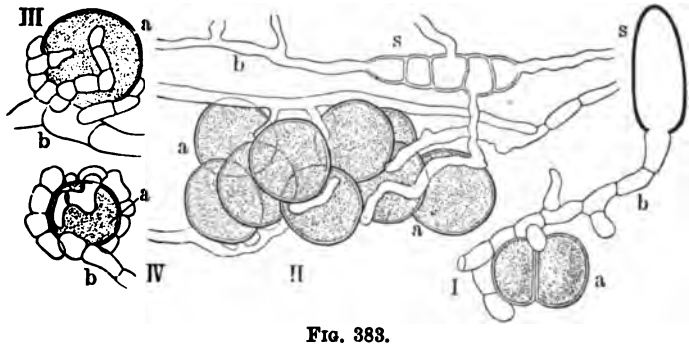


FIG. 383.

I. Germinating spore of *Physcia parietina*, attached to *Protococcus viridis*; II. The same of *Biatora muscorum*; III. IV. The same of *Cladonia furcata*; 950 times enlarged.—(After Bornet.)

Figure 383 represents some examples of the symbiosis of hyphæ and gonidia, such as have actually been seen to occur in experimental culture. In I. we have a germinating spore of a lichen, *Physcia parietina* (*s*). From it has issued the filament (*b*) which is just about to attach itself to an Alga (*a*, *Protococcus viridis*). Figure II. represents a spore (*s*) of *Biatora muscorum*, the hyphæ (*b*) of which are intertwined with the *Protococcus* colony (*a*). In III. and IV. single gonidia (*Protococcus* cells) from the thallus of *Cladonia furcata* are shown, so as to illustrate their connection with the hyphæ.

Typical genera of lichens are — *Cladonia* (many species of which are common in woods and on heaths), *Stereocaulon*, *Lecanora*, *Peltigera* (shield-lichens growing among moss), *Parmelia* (on trees and stones), *Usnea barbata* (on the branches of trees in forests), *Ramalina fraxinea*, *Cetraria islandica* (Iceland moss), *Roccella tinctoria* (litmus lichen), &c. The reindeer lichen, *Cladonia rhangiferina*, which covers large stretches of land in Siberia, is important as fodder for reindeer.

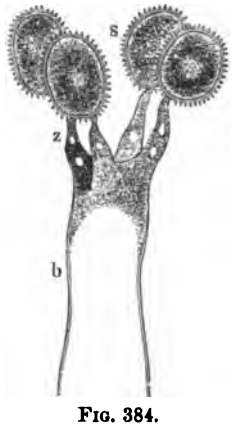


FIG. 384.

Basidium with four ripe prickly spores of *Corticium amorphum*, *Fr.* 390 times enlarged.—(After de Bary.)

(4.) *Basidiomycetes.*—Spores not enclosed in an ascus, but borne on a basidium-cell (Fig. 384), singly or in groups, mostly of four. All the spores on the same basidium ripen at the same time. The basidia are the ends of hyphæ arising from under the receptacle, which, standing together upright, form the *hymenium.* This varies much in shape, and is found either on the under side of the receptacle or in its interior; in the latter case it is surrounded by a tough or by a delicate membrane (*peridium*).

The Basidiomycetes are divided into three families—the *Tremellini*, the *Gasteromycetes*, and the *Hymenomycetes;* the two latter are divided into a number of groups.

1.—*Families of Basidiomycetes.*

I. Fructification or receptacle a soft gelatinous mass, of indefinite form; basidia on the upper surface imperfect, . . . 1. TREMELLINI.

II. Receptacle of definite form, fleshy or tough.

A. The basidia develop in the interior of a hymenium, in cells or chambers, . . . 2. GASTEROMYCETES.

B. The basidia are situated externally on a hymenium covering a definite part of the receptacle, . 3. HYMENOMYCETES.

2.—*Groups of Gasteromycetes.*

I. Receptacle *subterranean, remaining closed,* only appearing above ground when ripe, *a.* HYMENOGASTREI.

II. Receptacle appears above ground, opens.

A. Receptacle with interior column, which on maturing breaks through the peridium, and bears at its apex the slimy, stinking hymenium, which soon disappears, ... *b.* PHALLOIDEI.

B. Receptacle without interior column.

* Receptacle small, cup-shaped on opening. Hymenium enclosed in several small lenticular bodies, or in a single spherical body, *c.* NIDULARIEI.

** Receptacle large, peridium membranous, opening mostly at the apex. Hymenium resolves into a filamentous tissue and spore powder, *d.* LYCOPERDEI.

3.—*Groups of Hymenomycetes.*

I. Hymenium situated on the upper side of a vertical receptacle, club-shaped, or borne on rounded branches, ... *a.* CLAVARIEI.

II. Hymenium situated on the under side of a fleshy receptacle, or on the under side of a membranous receptacle.

A. Hymenium smooth, or dark and rough, . .	*b.* THELEPHOREI.
B. Hymenium forms radiating lamellæ, or tubes, pores, pits, or, more rarely, conical points or papillæ.	
1. Hymenium forms conical points or papillæ, which are rarely leaf-shaped, still more rarely regularly disposed prominences on the under side of the receptacle, . .	*c.* HYDNEI.
2. Hymenium not as preceding.	
* Hymenium forms tubes, pores, or pits, which occupy the whole under surface of the receptacle; more rarely they are arranged round the edge, or on tubular papillæ,	*d.* POLYPOREI.
* * Hymenium forms lamellæ or folds radiating from the stalk; the lamellæ occasionally anastomose, and consequently seen pitted,	*e.* AGARICINI.

1. *Tremellini.* — These form a gelatinous, trembling, transparent mass, the surface of which is quite covered with spores. *Tremella mesenterica* is golden yellow in colour, and appears in spring on fallen twigs.

2. *Gasteromycetes*—(*a.*) *Hymenogastrei.*—Externally like truffles. *Rhizopogon* (about the size of a potato), *Hymenogaster* (size of a nut). (*b.*) *Phalloidei.*—Fructification at first egg-shaped, but after the column bearing at its apex the slimy, greenish mass of spores has pierced the peridium, the fungus looks like a hymenomycete. *Phallus impudicus* (stinkhorn), common in woods. (*c.*) *Nidulariei* like *Peziza* among the Ascomycetes; *Cyathus* (growing on rotten wood), *Nidularia*, &c. (*d.*) *Lycoperdei.*—The peridium is tough and leathery when immature, whitish, grey, or light brown in colour, and covered with warts or scales (external peridium). It opens mostly by a pore at the top, or irregularly, and scatters abroad its snuff-coloured spores in thousands. *Lycoperdon* (puff-ball), *Bovista* (common in meadows, pasture land, and grassy spots), *Geaster* (external peridium opens like a star, with valves thrown back; found in woods).

3. *Hymenomycetes* (*Mushrooms*).—The most highly developed of all fungi. (*a.*) *Clavariei*, receptacle mostly branching like coral, fleshy (Fig. 385); typical genus *Clavaria*, comprising numerous species. The following are edible:—*C. crispa*, *C. brevipes*, *C. aurea*, *C. grisea*, *C. botrytis*, *C. amethystea*, *C. coralloïdes*, *C. cinerea*. (*b.*) *Thelephorei*, found on fallen branches and trees, which they injure; one genus, *Thelephora*. (*c.*) *Hydnei*, found on old wood and bark. (*d.*) *Hydnum* (*Polyporeæ*), receptacle fleshy, corky, woody (Fig. 386) or hard, mostly without stalks, *Boletus* and a few species of *Polyporus* being exceptions. *Polyporus*, *Fistulina*, *Dædalea* are found on

tree trunks; *Merulius lacrymans* (dry rot, grows in and on damp wood, first covering it with a mould-like coating, and afterwards, in its mature state, exuding moisture in drops); *Boletus* (many species, among which is *B. edulis*, a highly prized edible fungus). Other species are *B. luteus*, *B. bovinus*, *B. badius*, *B. subtomentosus*, *B. variegatus*, *B. regius*, *B. versipellis*, *B. scaber*, *B. castaneus*. The following are poisonous:—*B. squamiger*, *B. piperatus*, *B. radicans*, *B.*

FIG. 385.

FIG. 386.

Hymenomycetes.—Fig. 385.—*Callocera viscosa.* Fig. 386.—*Polyporus versicolor*; nat. size.

calopus, *B. pachypus*, *B. Satanas*. (*e.*) *Agaricini*, the largest division of the fungi comprises forty genera, each with many species; the most important edible and poisonous of these are the following:—*Amanita cæsarea* (of very pleasant flavour), *A. muscaria* (fly-agaric, very poisonous, used by the inhabitants of North-East Asia, in preparing a highly intoxicating beverage); *Lepiota delicata* and *L. procera*, of agreeable flavour; *Tricholoma Russula*, much used in Austria; *Paxillus panuoïdes*, poisonous; *Agaricus campestris*, the mushroom, a favourite edible species; *P. arvensis* and *P. silvatica* are less delicate in flavour; *Phlegmacium varium*, poisonous; *Hygrophorus eburneus*, edible; *H. conicus*, poisonous; *Lactarius deliciosus*, edible; *L. scrobiculatus*, poisonous; *L. luridus*, poisonous; *L. plumbeus*, poisonous; *Cantharellus cibarius*, edible.

Type III.

ALGÆ.

The Algæ are never, like the fungi, composed of hyphal tissue. The vegetative body is unicellular, few-celled, or multicellular. When few-celled, it is frequently filamentous; when multicellular, it sometimes assumes the form of higher plants (*Characeæ*, and many seaweeds). The Algæ always contain green colouring matter (chlorophyll), or similar pigments, imparting a red, brown,

yellow, or olive colour to the organism, and capable, like ordinary chlorophyll, of carrying on the process of assimilation. The Algæ, accordingly, are not parasites, but independent plants. The process of sexual reproduction differs much in different species, as we shall see later. They are grouped into numerous orders, of which the most important are the following :—

Chief Orders of Algæ.

I. The two sexual cells *homogeneous;* sexual product a *zygospore.*

A. ZYGOSPOREÆ.

A. Unicellular Algæ.

a. Containing yellowish brown colouring matter (*diatomin*), with siliceous coat, — 1. DIATOMACEÆ.

b. Containing green colouring matter (*chlorophyll*), no siliceous coat, . . — 2. DESMIDIACEÆ.

B. Multicellular (filamentous) Algæ; green, . — 3. ZYGNEMACEÆ.

II. The two sexual cells *heterogeneous.*

A. Sexual product a *spore*, which either develops into a new plant, or generates swarm-spores.

B. OOSPOREÆ.

a. With green colouring matter (chlorophyll). Found in fresh water.

* Filamentous Algæ, consisting of branched, or unbranched, one or more celled, filaments.

1. Unicellular, ... — 4. VAUCHERIACEÆ.

2. Multicellular, . . . — 5. ŒDOGONIACEÆ.

* * Consisting of a multicellular vegetative body, ... — 6. CHARACEÆ.

b. With red or olive brown colouring matter, inhabiting salt water, . . . — 7. FUCACEÆ.

B. Sexual product a *sporocarp*, producing spores.

C. CARPOSPOREÆ.

One family, mostly sea-weeds, not green, . — 8. FLORIDEÆ.

A. *Zygosporeæ.*

The Algæ belonging to this class are mostly unicellular organisms (*Desmidiaceæ, Diatomaceæ*); more rarely the vegetative body consists of a many-jointed cell filament (*Zygnemaceæ*). Reproduction takes place *asexually* by division of the cells in the longitudinal or the transverse direction. Reproduction also takes place *sexually*, the sexual cells so produced not being, as in

the following types, of different form. Sexual reproduction is effected by means of *conjugation* (see p. 270). The cell arising as the result of conjugation is a *zygospore* (*o*, Fig. 341), formed by the fusion of the protoplasmic contents of two cells. Previous to germination the zygospore remains for some time in a state of rest (*resting-spore*). The three following orders may be mentioned:—

(1.) *Diatomaceæ* (*Bacillariaceæ*).—Unicellular Algæ, containing brownish yellow colouring matter (*diatomin*). Occasionally a number of individuals unite to form a band-shaped colony. The cell-membrane is highly siliceous (comp. p. 248), the silex being incorporated with the tissue of the membrane in the form of dots, lines, tubercles, or irregular masses and such-like. After the decay of the organic constituents of the plant, the delicate siliceous skeleton often remains intact (Fig. 387). The Diatom cell consists of two halves symmetrically divided in the long direction; the one-half is a little broader than the other, its edges overlapping like those of a lid. In the process of division the two halves separate, and the inner or small half has to be formed anew. Hence, under continuous division, the cells are always getting less. A limit is, however, put upon this progressive diminution by the formation of *auxospores*, a process which takes place either by *rejuvenescence* or by *conjugation*. In the former case (*Melosira*) a cell formed in the usual manner by division discharges its protoplasmic contents, and these subsequently develop into the auxospore; in the latter (*Frustulia*) two cells enter into conjugation, their contents pass out and fuse, a zygospore being thus formed, from which the auxospore is afterwards developed. The auxospore is always much larger than the two mother cells.

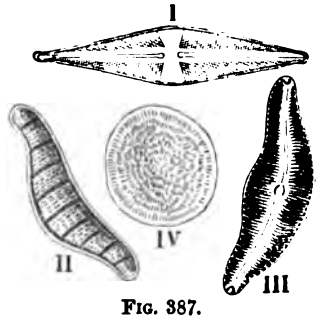


FIG. 387.

Fossil Diatoms from Ebstorf.—I. *Fragilaria*. II. *Epithemia*. III. *Cocconema*. IV. *Gallionella*. 600 times enlarged.

There are in all about 1500 known species of Diatomaceæ; they abound both in fresh and salt water. Many fossil forms occur. The great deposits of "Tripoli," and the so-called "Infusorial Earth" are in great part made up of the siliceous skeletons of Diatomaceæ, which have been able through ages to withstand decay.

(2.) *Desmidiaceæ.* — Mostly unicellular Algæ, coloured green by chlorophyll (see Fig. 342, p. 271), often stellate or crescentic in shape. Reproduction proceeds *asexually* by cell-division, *sexually* by conjugation. The latter process takes place as follows:—Two cells arrange themselves crosswise, with their broad sides facing one another; the walls then give way, and the protoplasmic contents of the two cells mingle. The result is a resting zygospore, in which afterwards arise two new individuals. The Desmidiaceæ are only found in fresh water—in pools.

(3.) *Zygnemaceæ* (*Filamentous Algæ*).—These contain chlorophyll, which is frequently distributed in the cells in the form of irregular masses or spiral bands (Fig. 334). Cells united to form unbranched filaments.

The filamentous Algæ form green, slimy flocculent masses in ditches and ponds; typical genera, *Zygnema, Spirogyra, Zygogonium.*

B. *Oosporeæ.*

The Oosporeæ are rarely unicellular (*Vaucheria*). Usually the vegetative body consists of cells arranged in rows, filaments, or masses of varying thickness. Like the Zygosporeæ, the Oosporeæ have a twofold mode of reproduction. The one is asexual (vegetative), and takes place by cell-division or by swarm-spores; the other is sexual. In sexual reproduction two kinds of cells are involved—a male (♂), the *Antheridium*, and a female (♀) the *Oogonium. The sexual cells differ in appearance from each other.*

Although in many minor details the different species vary considerably as regards their mode of reproduction, the general characteristics are the same in all. The method of reproduction seen in *Vaucheria* may be taken as typical (Fig. 388). The *Vaucheriæ* are *unicellular* Algæ having a filamentous, repeatedly branching body (I.); the branches (*d d e*) are blunted at the ends, and contain numerous large chlorophyll grains. From time to time two slight protuberances (♂, ♀ II.) appear side by side on one of the branches. These gradually increase in size and assume a cylindrical appearance, after which they undergo a remarkable series of changes. The protuberance destined to become an antheridium (III.) retains its cylindrical shape, but curves at the point into the form of a hook. At the same time it is divided about half-way up by a transverse wall (III.), whereby the anterior

portion (*b*) is transformed into a separate cell. This is the male cell. Gradually its chlorophyll disappears, its protoplasm is altered and breaks up into a number of minute masses, which, on the rupture of the cell-wall, pass out as *spermatozoids*. The spermatozoid (IV.) is extremely minute, and consists of a colourless protoplasmic mass, provided with two cilia (see IV.) by which it rapidly moves through the surrounding water. The development of the oogonium is as follows:

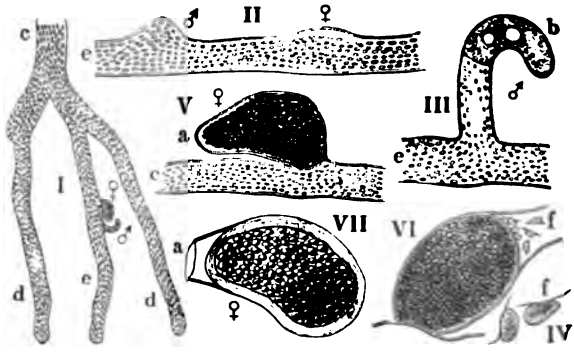


FIG. 388.

Sexual reproduction in a Vaucheria.—I. End of a branched cell; *d d e* Branches; ♂ and ♀ The sexual organs; II. Part of a filament showing the orgin of the sexual organs; III. A young antheridium; IV. Two spermatozoids; V. Unfertilised oogonium; VI. The same at the moment of fertilisation; VII. The embryonic vesicle after being detached from the parent plant. I. 100 times enlarged; II., III., V., VI., VII. 600 times enlarged; IV. 1000 times enlarged (see text).

—The protuberance on the branch of Vaucheria (♀, II.) gradually enlarges, becoming ovoid in shape, and assuming an oblique position. It is finally separated from the parent plant by means of a transverse wall formed at its base (*a*, V.). The contents of the oogonium are very dense, consisting wholly of opaque, granular, starchy matter. When the oogonium is ripe its contents are slightly withdrawn from the beak-like apex (*a*), which thereafter opens (*f*, VI.). The spermatozoids, liberated from the antheridium of the same or of some other individual, pass into the oogonium by the opening at *f*, and there continue in motion for some time. In the course of their movements the spermatozoids repeatedly come into contact with the granular plasma of the female organ, with which finally a number of them become incorporated. This constitutes the act of fertilisation (p. 168). The oogonium now surrounds itself with a firm membrane consisting of three layers, and detaches itself from the parent plant; its contents turn to a brown or reddish colour. The oogonium is now an *oospore* (VII.) After resting for some time, it develops into a new plant.

To illustrate the germination of the oospore, the case of a *Chara*

may be taken (Fig. 389). The oospore of Chara, after being detached from the parent plant, is somewhat barrel-shaped (I.), and is enclosed by a brown, almost opaque, envelope, furnished with spiral ridges. It is densely filled with colourless fat and starch granules. The process of germination is commenced by the withdrawal of the contents of the oospore from its apex, and the appearance in their place of clear protoplasm. A transverse partition is now formed across the interior of the oospore (I.) in such a manner as to give rise to a large basal cell and a smaller anterior one (*k*). The latter next divides transversely into two daughter cells, one of which develops into the primary root (*v*, II.), the other into the pro-embryo (*w s*). The pro-embryo then undergoes repeated division, and gives rise to the stem and secondary roots from the cells (*s* and *w*) thus formed.

In certain other species belonging to this class the oospores do not directly develop into new plants; their contents break up into swarm-spores, which germinate after liberation from the mother cell.

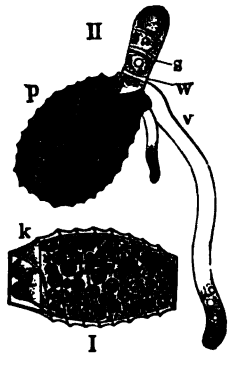


FIG. 389.

Germinating oospores of Charæ.—I. First stage of germination in the spore of *Chara crinita*. II. Spore with seedling plant issuing from it (*Tolypella intricata*). *s* Cell, from which the stem develops later on; *w* Original mother cell of the root; *v* Root (primary root); *p* Spore; *k* Anterior cell; about ninety times enlarged.—(After de Bary.)

(4.) *Vaucheriaceæ.* — Thallus a unicellular, ramifying tube, firmly attached to the underlying rock, &c. by root-like organs (rhizoids). It is lined with protoplasm, and contains numerous green chlorophyll grains. Vegetative reproduction takes place by spores; the end of a branch swells out, and is cut off from the parent plant by means of a transverse partition. Finally, the spore drops off, and after resting a few days germinates directly. In other species the contents of the spore (*Zoosporangium*) develop into swarm-spores, which on being liberated assume a rounded form, and give rise to new plants. Sexual reproduction takes place by antheridia and oogonia (see above).

(5.) *Œdogoniaceæ.*—Thallus a multicellular, simple, or branched tube, containing chlorophyll. Sexual reproduction effected by antheridia ánd oogonia; from the oospore proceed swarm-spores as in many Vaucheriaceæ.

Like the Zygnemaceæ the Œdogoniaceæ form dark green flocculent masses on stones and plants in water; they afterwards become detached, and float about freely. *Œdogonium*, *Bulbochæte*, *Coleochæte*, typical genera. Very similar, and perhaps allied to the Œdogoniaceæ

are the *Confervaceæ*, of whose mode of reproduction much has yet to be learned.

(6.) *Characeæ*.—Sexual reproduction effected by antheridia and oogonia of very complicated structure; large multicellular plants, allied in many respects to the higher plants (mosses); readily distinguishable from all other Algæ by their peculiar habit. The "stem" grows vertically upwards, giving rise at intervals to branches arranged in a verticillate manner, on which, or on the twigs of which, are the sexual organs.

FIG. 390.

Melanthalia Billardierii (*Mons.*); three times enlarged. A species of Florideæ from the coast of Van Diemen's Land. *s* Stem. *d* Leaf-like lobes of the thallus, *f* cystocarp.

Submerged plants, rooting in mud, and attaining a height of about 30 cm. Found in ditches, brackish water, &c. Typical genera, *Nitella*, *Chara*.

(7.) *Fucaceæ* (*Sea-Wracks*).—Salt-water Algæ with peculiar greenish brown colouring matter, often of enormous size; firmly attached to the sea-floor by means of rhizoids; the thallus sometimes appearing above water.

In habit the Fucaceæ frequently resemble large phanerogams (trees, shrubs), but are nevertheless cellular cryptogams. *Fucus vesiculosus* (bladder-wrack) is a well-known species; *F. serratus* is common on the coast of Britain; *Sargassum bacciferum* forms in certain parts of the ocean (Atlantic Ocean) large floating islands of tangle; sea-wracks grow most richly in the neighbourhood of Magellan's Straits.

C. *Carposporeæ*.

Multicellular Algæ, not green in colour. The sexual product is not, as in the case of the Oosporeæ, a spore, but is usually a multicellular body, the *sporocarp* or *carpogonium* (comp. p. 318) in which, after fertilisation, the spores are generated. Fertilisation is effected either by swarm-spores (spermatozoids) or by conjugation of the two sexual cells. Almost all Algæ of this class are sea-plants.

(8.) *Florideæ*.—The Florideæ are sea-weeds containing red or brown colouring matter. They are distinguished from the sea-

wracks by the circumstance that their spores are generated in capsules (*cystocarps, f*, Fig. 390), which arise in the axils of the leaf-like lobes of the thallus (*s, d*).

A fresh-water species of Florideæ is *Batrachospermum moniliforme*. This is a slimy Alga, measuring only a few centimetres, and composed of numerous rows of cells arranged in bead-like bunches. Found in clear running water, attached to stones, wood, &c.

Second Series.

MUSCINEÆ.

The Muscineæ constitute the link between cellular and vascular plants. The stems of the Muscineæ are characterised by a very imperfect central fibro-vascular bundle, in which the vessels are usually entirely awanting, and only cambiform tissue present. The vegetative body is differentiated into stem and leaves, except in the case of certain lower forms (frondose liverworts), where it is not developed beyond the thallus stage. Reproduction is effected both sexually and asexually. Asexual reproduction is effected by *gemmæ*, those peculiarly modified hairs already described on p. 281. Sexual reproduction is in all cases effected by *Antheridia* and *Archegonia*, which are also to be regarded as modified hairs. They are found on full-grown

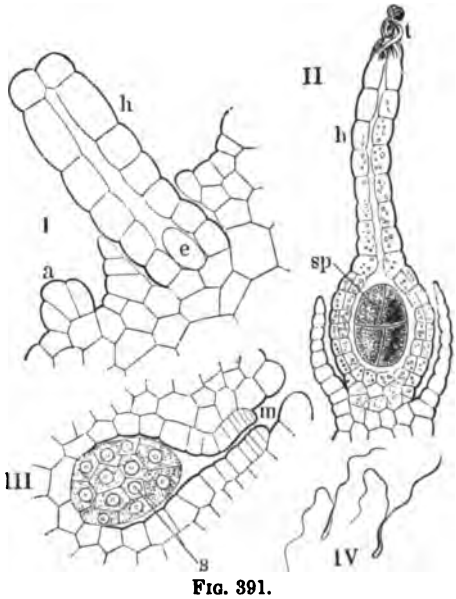


FIG. 391.

Antheridium and archegonium of liver-worts. —I. Young archegonium of *Riccia ciliata;* II. More advanced archegonium of *Marchantia polymorpha;* III. Young antheridium of *Riccia glauca;* IV. Spermatozoids of *Marchantia polymorpha*. *a* Base of the archegonium; *h* Neck of do.; *t* Dried apex; *e* Embryonic cell, after fertilisation by cell-division, developing into the sporocarp (*sp*, very early stage); *s* Cells about to form spermatozoids. I. (According to Kny), 440 times enlarged. II. (According to Sachs), 300 times enlarged. III. (According to Hofmeister), 500 times enlarged. IV. (According to Sachs), 800 times enlarged.

plants, and arise from the cells of the epidermis. The antheridia are ovoid or clavate in shape (Fig. 391, III.), and consist internally of a mass (*s*) composed of sperm cells (♂). In these the *spermatozoids* are generated, each cell producing a single spermatozoid. To effect fertilisation the spermatozoids pass out of the antheridium by the narrow passage (*m*), and enter the archegonium. The latter, the female organ, is flask-shaped, and opens outwards by a narrow, neck-like passage (*h*, I.). It is composed of cellular tissue, and encloses a central cell, the *oosphere*. The spermatozoids (minute elongated bodies, provided with two cilia, IV.) having left the antheridium, pass along the neck of the archegonium (*h*), come into contact with the oosphere (*e*), and blend with it (fertilisation). Thereupon the

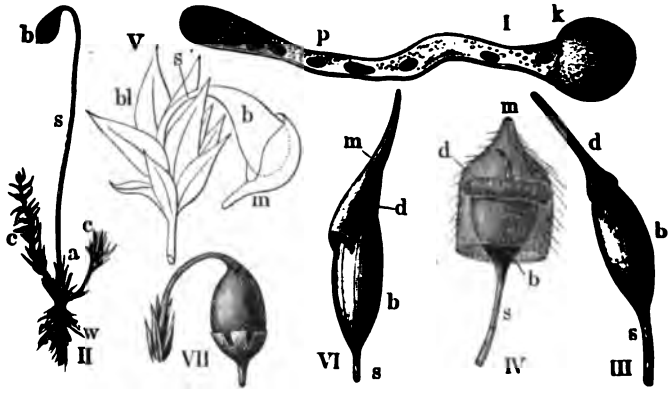


FIG. 392.

Liver-worts.—I. Germinating spore of *Ceratodon purpureus;* II. Fructifying plant of *Bryum Warneum;* III.-IV. Capsules; III. *Ceratodon purpureus;* IV. *Pogonatum nanum;* V. *Physcomitrium curvisetum;* VI. *Cynodontium gracilescens;* VII. *Racomitrium patens.* I. 600 times enlarged; II. Nat. size; III.-VII. About 10 times enlarged. *w* Root, *c* Leaf twigs, *s* Stalk of capsule (*Seta*), *b* Capsule, *d* Valve, *m* Cap, *bl* Leaves, *k* Spore, *p* Protonema.

oosphere divides (*sp*, II.), and develops into a sporogonium (capsule) of considerable size, in which the spores appear later on. The sporogonium of the mosses is universally known. It is borne at the end of a long stalk (*s*, Fig. 392), and is often surmounted by a cap (*m*) representing the upper half of the wall of the archegonium, which gets torn across as the capsule enlarges. When ripe, the sporogonium opens by means of a

valve (*d*), in the liver-worts by four longitudinal slits. The rim of the capsule is frequently bordered by a row of peculiarly shaped teeth forming the *peristome*. When the capsule opens numerous brownish spores are scattered abroad. These germinate in damp soil, their outer wall (*k*, I.) giving way, and a colourless germ-tube, containing large chlorophyll grains, being protruded. The germ-tube is soon divided into rows of cells, ramifies, and forms a filamentous algoid body, the pro-embryo or *protonema*. In course of time a short bud is formed on one of the branches of the protonema. By cell-division this bud speedily develops into a mass of cells, part of which grows in an upward direction, and produces a leafy moss (sexual generation, *a c c*). Another portion of this tissue grows downwards, and forms the root (*w*).

Type IV.

HEPATICÆ (LIVER-WORTS).

The protonema is absent or very small. Vegetative body thallus-like (*Anthoceros*, *Marchantia*), or consisting of a repeatedly branching stem with small flat leaves (*Jungermannia*). The capsule (sporogonium) is usually stalked, and of oval, spherical, or like shape. It contains numerous minute spores, and certain peculiar structures called *elaters*. These are composed of elastic filiform cells; their function is to cause the spores to spring from the open capsule on the slightest provocation. The sporogonium usually opens by four vertical slits.

The liver-worts are the lowest of the Muscineæ. They are small delicate plants which grow on the trunks of trees, on walls, on the ground, on decaying leaves and elsewhere. Typical genera are *Riccia* (*R. natans* and *R. fluitans*, float on the surface of lakes), *Anthoceros*, *Marchantia* (*M. polymorpha* is the commonest of all the liver-worts), *Fegatella*, *Lunularia*, *Blasia*, *Jungermannia*, *Metzgeria*, *Aneura*, &c. &c.

Type V.

MUSCI (MOSSES).

The pro-embryo or protonema is large, and is composed of branching filaments containing chlorophyll. When full grown the vegetative body is always differentiated into stem and leaves; the latter may or may not have a simple midrib, and

are for the most part composed of one kind of tissue. The sporogonium (capsule) is mostly stalked, and bears at its apex a cap, *i.e.*, the upper portion of the former archegonium wall. The tissue in the interior of the capsule produces only *spores;* elaters do not occur. The central tissue of the capsule is barren, and produces no spores; in the ripe sporogonium it forms the central *columella.* The capsule opens by means of a deciduous lid, with or without a peristome, rarely by four vertical slits. Still more rarely the capsule remains closed, and the spores are liberated after the decay of its walls. The most important orders are as follows :—

(1.) *Sphagnaceæ* or *Bog-mosses.*—Without cap (*calyptra*). Capsule without proper stalk, but borne at the end of a stalk-like process of the stem, opening by a lid. Pro-embryo (protonema), like the prothallus of a fern (see below), flat and leaf-like.

The bog-mosses are distinguished by their peculiar yellowish green, yellow, or reddish colour. They abound in boggy places. There is but one genus, *Sphagnum* ; about twenty species are known in Europe ; the chief are *S. squarrosum, S. cuspidatum, S. rigidum, S. cymbifolium,* &c.

(2.) *Andreæaceæ.* — Mosses with calyptra; capsule without proper stalk, as in sphagnaceæ. It opens by four vertical slits, which reach nearly to its summit. Protonema filamentous.

Small, almost black, mosses, growing on rocks and stones. One genus, *Andreæa* (*A. rupestris* and *A. petrophila*), is common in mountainous regions.

(3.) *Bryaceæ.*—Mosses with calyptra, capsule borne on a true stalk (*seta*), which is rarely short; it opens by a lid (*operculum*), and frequently possesses a peristome; sometimes it remains closed. Protonema filamentous.

The Bryaceæ are small or moderately large plants which grow together in large numbers, and cover the surface of the ground, of stones and rocks, and of trees ; some species grow in water. They display great diversity in general habit, and in the form of the capsule. They are divided into *acrocarpous* and *pleurocarpous* mosses, according as the capsule arises from the apex or from the side of the stalk. Recently they have been further subdivided into numerous families, which need not be considered here. The most important genera are as follows :—*Phascum* (capsule remaining closed), *Weisia, Dicranella, Dicranum* (*D. scoparium,* very common in woods),

Fissidens (with imbricated leaves arranged in two rows), *Pottia*, *Ceratodon* (*C. purpureus* is one of the commonest of the mosses, and is found in nearly all parts of the world), *Trichostomum*, *Barbula*, (with spiral peristome), *Grimmia* (growing in cushion-like masses on rocks), *Racomitrium*, *Ulota* (found on trees and rocks), *Orthotrichum* (the same), *Schistostega* (growing in crevices, with a protonema which shines in the dark), *Splachnum* (with peculiar capsule), *Funaria*, *Bryum* (a large genus, comprising many species which cannot easily be distinguished from each other), *Mnium*, *Polytrichum* (a woodland genus), *Fontinalis* (found in mountain brooks), *Thuidium*, *Climacium*, *Isothecium*, *Brachythecium*, *Eurhynchium*, *Rhynchostegium*, *Plagiothecium*, *Amblystegium*, *Hypnum* (very large genus), *Hylocomium*. The last eleven genera are all pleurocarpous. Over 6000 species of Bryaceæ are known.

Third Series.

VASCULAR CRYPTOGAMS, OR VASCULARIA.

The vascular cryptogams (ferns, &c.) resemble the mosses, but they differ from them in many important respects, and possess many features in common with the higher plants, particularly the conifers.

The prothallus or *prothallium* produced as the first result of the germination of the spores of vascular cryptogams is a flattish or rounded cellular body divided into lobes. It is attached to the soil by numerous root-hairs, called *rhizoids*. The prothallia of most true vascular cryptogams appear above the ground and contain chlorophyll. Those of the Ophioglosseæ and Lycopodiaceæ are, however, subterranean, and do not contain chlorophyll. It is on the prothallia that the male and female sexual organs (antheridia and archegonia) are borne. In some cases the two kinds of sexual organs (sporangia) are produced on the same prothallium, but in others (Equisetaceæ, Rhizocarpeæ, Selaginelleæ) the male organs are produced on one set of prothallia, the female on another.

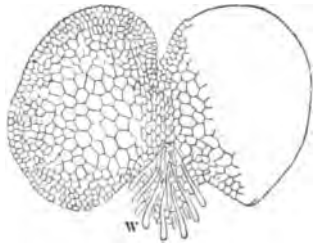


FIG. 393.

Prothallium of one of the Vascularia, *Aspidium setigerum*; 50 times enlarged. *w* Root-hairs.

The structure of the *antheridium* differs in different groups. In many (Polypodiaceæ) it is as follows (Fig. 394):—It is

enclosed by a cellular (epidermic) wall (*a*), the apex being formed by a single cell, which acts as a lid (*h*). This cell has here given way. The interior is composed of cellular tissue, in the cells of which, at a later stage, the spermatozoids are developed. When the antheridium is ripe, the apical cell opens by a slit, and the cells containing the spermatozoids are thus discharged. The spermatozoid proper lies coiled up spirally in its cell (*s*), in which it keeps up a rotatory movement. Suddenly it bursts through the surrounding protoplasm (*s'*), and moves away with a peculiar winding or boring movement (*s''*) in search of the archegonium.

The *archegonium* is similar in structure to that of the Hepaticæ and the mosses. Like the latter, it is flask-shaped, the lower part being bulged out, the upper narrow and neck-like (*h*, Fig. 395). The egg-cell or oosphere (*e*) lies in the lower part

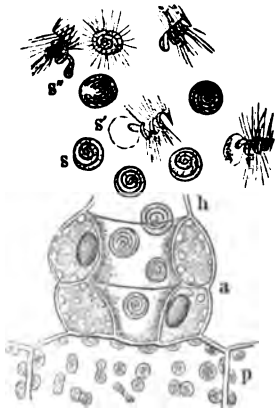


FIG. 394.

FIG. 395.

Fig. 394.—Antheridium of *Pteris serrulata* showing the discharge of spermatozoids. Some of these are already some way off. 350 times enlarged.—(After Luerssen.) Fig. 395.—Ripe archegonium of *Osmunda regalis*. *h* Neck; *e* Oosphere. 240 times enlarged.—(After Luerssen.)

of the organ. There it is reached by the spermatozoids, which blend with it, and so fertilise it. After fertilisation, the embryonic cell undergoes repeated division. First of all it is divided into four compartments, one of which forms the primary cell of the future root; the second, that of the stem; the third, that of the first leaf; and the fourth, that of the so-called *foot*. The *foot* is composed of a mass of cells of considerable size, form-

ing the connection between the seedling plant and the prothallium; it absorbs nourishment from the prothallium, with which it supplies the young plant until the latter is able to support itself.

We thus see that, in the Polypodiaceæ and kindred plants, what is commonly called the fern is the result of the development of the embryonic cell of the archegonium after fertilisation. It constitutes the asexual *generation*, while the prothallium represents the *sexual generation*.

The so-called "fern,"—*i.e.*, the axis and its fronds—is accordingly the *homologue* of the capsule of the mosses. *The moss sporogonium and the spore-bearing fern plant are thus, viewed from the standpoint of comparative morphology, homologous structures.*

The asexual spore-bearing generation must be considered under each type separately, as in each it is characterised by special peculiarities.

Type VI.

Filicineæ (Ferns).

In the true ferns (*Filices, Filicineæ*) the prothallium is flattish or slightly globular. Antheridia and archegonia develop on the same prothallium. The spore-bearing generation consists of a well-developed or much-shortened stem, which may be either simple or slightly branched, and which bears numerous more or less divided compound leaves (fronds). The spores are borne on the fronds, mostly on the under surface, and are enclosed in peculiar capsular spore-cases, called *sporangia*. The ferns produce only one kind of spores.

The sporangia are metamorphosed hairs (comp. p. 280). They develop on the leaves in groups (*h*, I., Fig. 396), the group receiving the name of *sorus*. The sorus is usually surrounded by or enclosed in a scale-like membranous structure (*indusium*) continuous with the epidermis of the leaf. The capsules or sporangia constituting the sorus (II., III.) always arise by enlargement and division of one of the cells of the epidermis (hair-cell). They are usually stalks (*p*), and consist of a thin, transparent (hyaline) wall enclosing numerous spores (*s*). In most cases the wall of the sporangium possesses a ring (*annulus*) of thickened cells, which runs round the case and divides it externally into two halves. The opening of the sporangium when

ripe is effected by means of the annulus, which gives way at a certain spot, and curls backwards.

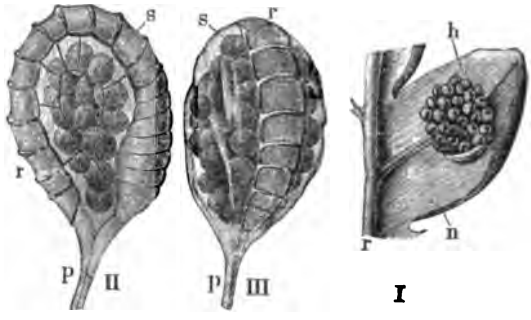


FIG. 396.

I. Pinna of *Polystichum spinulosum* (*n*) with sorus (*h*). II. Sporangium from the side. III. The same from behind. *p* Stalk; *r* Annulus; *s* Spores. I. ten times enlarged; II. III. 200 times enlarged.

The various positions occupied by the sporangia or sori may be well seen in Fig. 397–399, where we find illustrations representing the position of these organs in several of the most import divisions of the Filices. Fig. 397 represents the common hart's-tongue (*Scolopendrium vulgare*) reduced to about one-half the natural size. The under-surface of the simple frond bears numerous linear sori. Fig. 398, I.–III., represents single pinnæ of various other ferns (*Polypodium*, *Didymochlæna*, *Nephrolepis*); note here the regular way in which the midrib (*m*) branches, the sori (*s*) being seated on one of the smaller ramifications. In III. the kidney-shaped indusia which cover the sori may be plainly seen. In VIII. and IX. (*Pteris*, *Adiantum*), the sori are ranged along the margin of the pinnæ, which is slightly curved inwards, covering the sporangia, and so forming a *false indusium*. In *Lygodium*, one of the Gleicheniaceæ (IV., V.), the sori are arranged on an axis formed by the prolongation of a vein beyond the margin of the pinna; they are composed of several sporangia (in this case seven), and have a horizontal annulus; in the cut they are represented as open. The sporangia of Angiopteris, one of the Marrattiaceæ (VI.), are arranged in the manner shown in the cut: the sorus is without indusium. In *Marattia* the sporangia occur singly; they are thick-walled and open by a longitudinal slit. The two valves (*s*) each contain a row of small loculi (*f*). In the *Ophioglossaceæ* an entire leaf is metamorphosed into a spore-bearing organ (*f*, Fig. 399). It is easily distinguished from the sterile foliage leaves (*p*), its pinnæ being represented by small globular structures, which open later, and disclose the contained sporangia.

The Filicineæ are divided into three orders—the *Filices*, or true fern, the *Marattiaceæ*, and the *Ophioglosseæ* (adder's-tongues).

As these, in contrast to the Rhizocarpeæ, only produce one kind of spores, they are termed *isosporous.*

(1.) *Filices* (*Ferns*).—Prothallium appearing above the surface

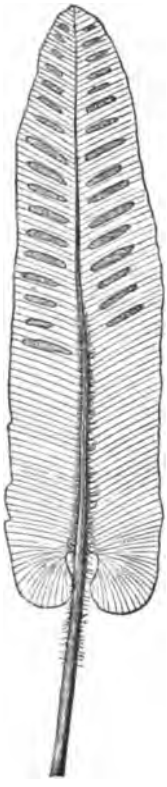


Fig. 397.

Scolopendrium vulgare (Hart's-tongue). Simple frond, with linear sori; half nat. size.

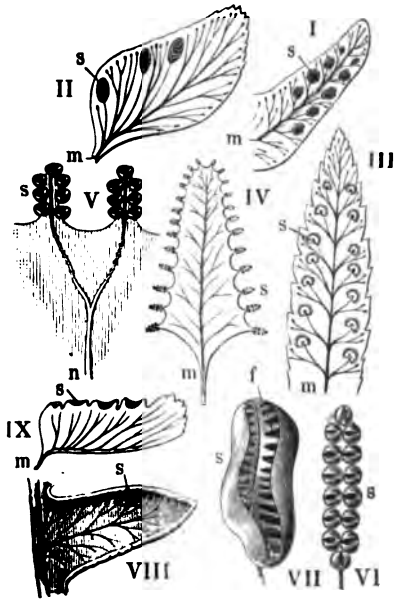


Fig. 398.

Sporangia of Ferns.—I. *Polypodium vulgare.* II. *Didymochlæna truncata* (J. Sm.). III. *Nephrolepis exaltata* (Schott). IV. V. *Lygodium.* VI. *Angiopteris.* VII. *Marattia.* VIII. *Pteris aquilina.* IX. *Adiantum Capillus-Veneris; m* Midrib; *n* Veins; *s* Sori. I.-IV., VIII., IX. nat. size; V.-VII. fifteen times enlarged.

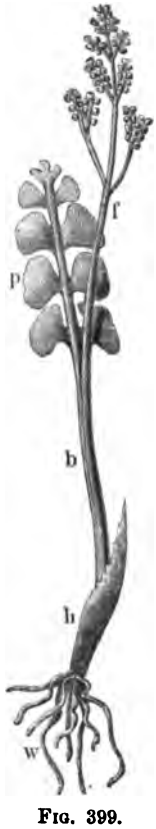


Fig. 399.

Botrychium Lunaria, nat. size. *w* Root; *h* Scale; *p* Frond; *f* Spike bearing sporangia.

of the soil, and containing chlorophyll. Sori free, arranged on the under surface, or at the margin of ordinary or slightly metamorphosed leaves. The young fronds circinate in vernation. Sporangia mostly with vertical annulus and indusium, never divided into chambers.

Almost all our native ferns belong to this order. Important species are—*Pteris aquilina* (bracken), *Adiantum Capillus-Veneris* and *A. pedatum* (maiden-hair)—(both these species, as well as many from South America, largely cultivated in hot-houses), *Cystopteris fragilis* (bladder fern), *Aspidium Filix-mas*, *Polypodium vulgare* (polypody), *Asplenium Filix femina*, *A. Ruta muraria*, *Scolopendrium* (hart's-tongue), *Struthiopteris germanica*, *Blechnum boreale* (hard fern), *Osmunda regalis* (royal fern). Many tropical ferns are tree-like, *e.g.*, *Dicksonia antarctica*, a species which may be met with in many hot-houses. Its stem attains a height of about forty feet, and the fronds a length of about fourteen feet; it is indigenous in New Holland and New Zealand. The allied genus *Cyathea* has several tree-like species with large beautiful fronds.

(2.) *Marattiaceæ*.—Prothallium appearing above-ground, containing chlorophyll; sori arranged on the under surface, or at the margin of ordinary (not metamorphosed) fronds. The young leaves are circinate in vernation. Sporangia without distinct annulus, without indusium, sometimes divided into chambers.

A small order, the species of which are mostly tropical; some are tree-like. Genera—*Angiopteris*, *Kaulfussia*, *Marattia*, *Danæa*.

(3.) *Ophioglosseæ* (*Adder's-Tongues*).—Prothallium subterranean, without chlorophyll. Sori borne in the interior of fronds metamorphosed, so as to look like a spike. The young leaves not circinate in vernation.

The Ophioglosseæ are a small group, comprising several small species of ferns. Three genera—*Ophioglossum*, *Botrychium*, and *Helminthostachys*. The two first are found in all parts of the world, the last is confined to Tropical Asia and Australia. The two most common home species are *Botrychium Lunaria* and *Ophioglossum vulgatum*.

Type VII.

RHIZOCARPEÆ.

The Rhizocarpeæ are chiefly distinguished from the Filicineæ by the formation of two kinds of spores (macrospores and microspores); they are therefore termed *heterosporous*. The macrospores produce a female prothallium bearing archegonia, the microspores a male prothallium bearing antheridia. The sporangia are borne externally in the vicinity of the roots. They are of two kinds, one containing only microspores, the other only macrospores; they either lie *together* in groups surrounded

by a membranous capsule (the sporocarp, Fig. 400, *f*, and Fig. 401, *f*), or macro- and microsporangia are *separate*, and enclosed in two different sorts of sporocarps. The young leaves are either circinate or simply folded in vernation.

The peculiar habit of the Rhizocarpeæ is illustrated in Figs. 400, 401. They derive their name from the fact that the sporocarps are always found in the vicinity of the roots; in *Salvinia* the sporocarp was even formerly regarded as a metamorphosed root. The macrospore on quitting the sporocarp germinates, *i.e.*, undergoes repeated cell-division, and produces a female prothallium,

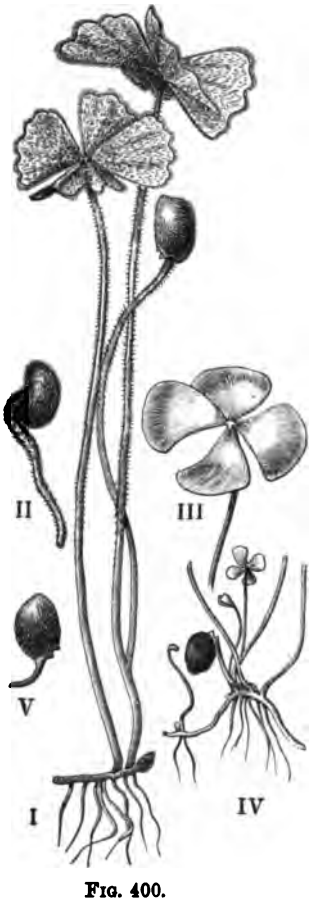


FIG. 400.

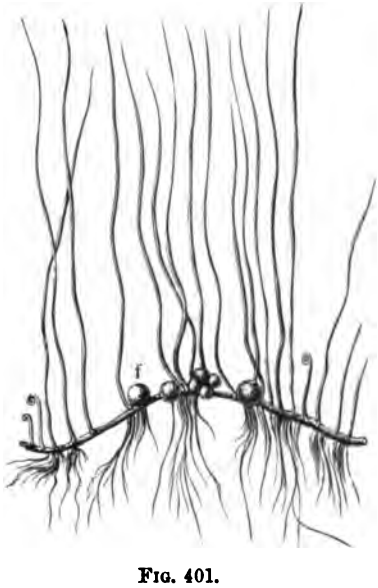


FIG. 401.

Fig. 400.—I. *Marsilia salvatrix* (Hanst.), entire plant; II. Young leaf. III.-V. *Marsilia uncinata* (A. Br.); III. Leaf; IV. V. Fruit; nat. size. **Fig. 401.**—*Pilularia globulifera* (Pill-wort); nat. size. *f* Fruits.

which continues in connection with the macrospore. The microspores in germinating either produce a very imperfect prothallium bearing antheridia, or their contents break up and form numerous spermatozoids. Two orders.

(1.) *Salviniaceæ.*—Macrosporangia and microsporangia separate, and enclosed in different unilocular sporocarps. Leaves folded in vernation.

Small plants without true roots, found floating on the surface of water; in habit resembling the duck-weeds. Two genera—*Salvinia* (native species *S. natans*) and *Azolla* (America, Africa, Australia).

(2.) *Marsiliaceæ.* — Macrosporangia and microsporangia enclosed in the same sporocarp. Leaves circinate in vernation (Figs. 400, 401).

Delicate land or marsh plants. Two genera—*Pilularia* (leaves filiform, pointed; indigenous, *P. globulifera*, Fig. 401) and *Marsilia* (leaves in whorls of four, Fig. 400; indigenous, *M. quadrifolia*).

Type VIII.

EQUISETINEÆ (HORSETAILS).

The Equisetums are distinguished from all other vascular cryptogams by the peculiar structure of the spore-bearing generation. The stem consists of a number of joints which fit into each other somewhat like the different pieces of a telescope. The true leaves are very small and membranous, and arise from the summit of each joint so as to surround the lower end of the joint immediately above. The stem bears numerous branches, usually arranged in whorls. It is stiff and rigid in appearance, a circumstance which is to be accounted for by the large quantity of silica which is deposited within its epidermis.

The Equisetums are further distinguished by the peculiar anatomical structure of the stem, in which they approach the dicotyledons, especially the conifers. Surrounded by the pretty equally developed fundamental tissue (*e k*, VII.), the fibro-vascular bundles lie in a ring (comp. Fig. 350), after the manner of those of the last-named plants. Immediately below the epidermis the fundamental tissue is entirely or partially transformed into sclerenchyma; further down come several layers of corticular parenchyma cells containing chlorophyll (*e*), then colourless cortical tissue without chlorophyll, and, finally, in the neighbourhood of the fibro-vascular bundles, similar tissue composed of somewhat smaller cells.

The stems of the Equisetums are traversed longitudinally by numerous tubular air-spaces. One of these always occupies the *centre* of the stem (*h*); in many species (*Equisetum palustre, arvense*) it is of small or of medium diameter; in others (*E. limosum*) it is very large. A circle of air-spaces is also found below the epidermis (*i*), and alternating with these is a second and much smaller set, which lie in close proximity to the fibro-vascular bundles (*g*).

All the Equisetums are perennial, and possess a solid rhizome, which produces a series of tubers lying one behind another.

At the end of the fertile stem the sporangia are borne in the form of a club-shaped spike or head (*a*, I.). The spike consists of several rows of stalked mushroom- or shield-shaped scales (II.), in which the spores develop. These peltate scales bear about eight pouch-like sporangia, which open by slits on their under and internal surface, and so liberate the spores. The spore is furnished with two elastic processes (elaters), which, when the atmosphere is damp, remain coiled firmly round it. When the air becomes dry, however, they gradually unwind (IV., V.), and assist in discharging the spore from the sporangium.

FIG. 402.

Equisetum arvense. — I. Fertile stem, nat. size; II. A peltate scale five times enlarged; III.-VI. Spores and elaters, 200 times enlarged; VII. Cross-section of stem, ten times enlarged. *a* Spike; *b* Node; *c* Peltate scale; *d* Stalk of do.; *e* Elaters; *f* Spore. (Explanation of VII. in the text.)

The spore germinates into a small prothallium, which bears either archegonia or antheridia. The antheridia contain small club-shaped spermatozoids, each provided with numerous cilia at the pointed end. The spermatozoids fertilise the embryonic cells of the archegonia in a manner similar to that observed in the mosses and ferns. The product of the fertilised archegonium is the spore-bearing Equisetum above described.

The type Equisetineæ includes but one order, the *Equisetaceæ*, with

one genus, *Equisetum*. The genus Equisetum includes very few species (Europe 12, Asia 14, America 21, Africa 3, New Holland 0). The most common home species are *E. arvense*, *Telmateja*, *pratense*, *sllvaticum*, *palustre*, *limosum*, *hiemale*. The Equisetums are not now so numerous as they were in earlier eras of the earth's history. Many fossil forms are met with, among which may be noted the Calamites, which attained the height and girth of trees. They were most plentiful during the carboniferous period.

Type XI.

LYCOPODINEÆ (*Club-Mosses*).

The Lycopodineæ are small or medium-sized plants, with strong or slender, repeatedly bifurcating, stems. The leaves are linear or scale-like, more rarely flat and green (Figs. 403, 404). In the Lycopodiaceæ (Fig. 403) the leaves are all of the same size

FIG. 403.

FIG. 404.

Fig. 403.—*Lycopodium inundatum*, nat. size. *s* Creeping stem ; *f* Fruit-spike. Fig. 404.—*Selaginella pubescens*. I. Leafy twig, six times enlarged ; II. End of twig, with spike (*c*), eight times enlarged ; *b* Lateral leaves ; *n* Median leaves.

and shape ; in the Selaginelleæ (Fig. 404) a double row of small leaves (median leaves, *n*), and a double row of larger leaves

(lateral leaves, *b*), are found. At the end of the stem the leaves are slightly metamorphosed, and form a club-shaped spike (*f*, *c*). In the axil of each leaf in the spike arises a kidney-shaped sporangium, which opens laterally. The Lycopodiaceæ produce only *one* kind of sporangia and *one* kind of spores (VIII., Fig. 405); the Selaginelleæ and Isoëteæ produce *two* kinds of sporangia (*macrosporangia* and *microsporangia*), and *two* kinds of spores (*macrospores* and *microspores*).

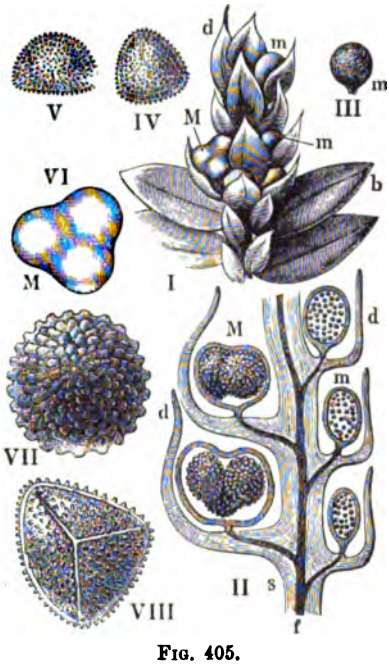


FIG. 405.

Lycopodineæ.—I.-VII. *Selaginella pubescens.* I. Lower part of the spike with macro- and microsporangia; ten times enlarged. II. The same, longitudinal section, somewhat diagrammatic; twenty times enlarged. III. Microsporangium; twenty times enlarged. IV., V., Microspores; 300 times enlarged. VI. Macrosporangium; twenty times enlarged. VII. Macrospore; seventy times enlarged. VIII. Spore of *Lycopodium complanatum;* 300 times enlarged. *s* Stem; *f* Vascular bundle; *b* Leaves; *d* Leaves of the spike; *M* Macrosporangium; *m* Microsporangium.

Fig. 405 I. represents part of the spike of *Selaginella pubescens*, somewhat enlarged. *M* is a macrosporangium, *m m*, microsporangia. The former is shown separately in VI., one of the latter in III. The longitudinal section through the spike shows the axis (*s*) with its central fibro-vascular bundle (*f*), and several leaves (*d d*). Those to the left are larger, and bear in their axils each a macrosporangium (*M*): the smaller leaves to the right bear in their axils each a corresponding microsporangium (*m*). The microsporangia contain numerous tetrahedral microspores (IV., V.); the macrosporangia, again, contain only four large, rounded, opaque macrospores (VII.), the surface of which is covered with small warts.

The spore of the Lycopodiaceæ germinates into a lobed prothallium, of whose development little is yet known. The sexual generation of the Selaginelleæ has been much more fully studied.

In these the microspore is observed to develop *in its interior* a rudimentary prothallium, bearing an antheridium, in which several spermatozoids are generated. The microspore is accordingly the male spore. The female prothallium is formed by repeated cell-division in the interior of the macrospore, which takes place while that organ is still attached to the parent plant, and not full-grown. After the spore has become detached, the rapid growth of the internal tissues causes the wall to give way, when the upper part of the prothallium slightly protrudes, and numerous archegonia are developed on its surface (*a a*, Fig. 406). The fertilised embryonic cell soon develops into an embryo, in which are to be distinguished, as in the case of the embryos of true seeds, a radicle (*w*), a stem (*v*), and two leaf-like structures (*k k*). A process (*t*) from the embryo passes upwards into the upper part of the prothallium, while it is connected with the lower part by the *foot* (*f*). Meanwhile the lower part of the prothallium has become modified into a firm tissue of polygonal cells (*e*), which contain a store of nutritive material for the support of the young embryo. This part of the prothallium accordingly corresponds to the albumen (endosperm) of the higher plants.

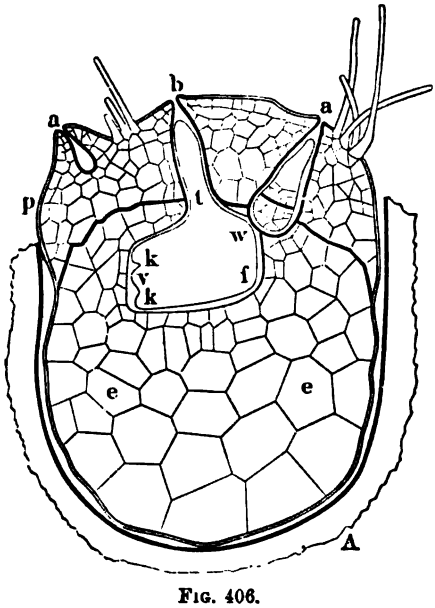


FIG. 406.

Longitudinal section through the macrospore of *Selaginella martensii*, showing the embryo, the prothallium, and the endosperm. *a a* Archegonia; *b* An archegonium at a more advanced stage; *w* Radicle; *v* Point of the stem; *k k* First leaves; *f* Foot; *t* Pro-embryo; *p* True prothallium; *e* Endosperm; *A* Wall of the macrospore; 165 times enlarged.—(After Pfeffer.)

The Lycopodineæ are divided into three orders:—*Lycopodiaceæ*, *Isoëteæ*, *Selaginelleæ*. The two most important are the Lycopodiaceæ and the Selaginelleæ.

(1.) *Lycopodiaceæ* (*Club-Mosses*). — Isosporous; prothallium monœcious; leaves small.

The Lycopodiaceæ comprise four genera, only one of which (*Lycopodium*) is indigenous in this country. The most important species are *L. Selago, annotinum, clavatum, inundatum, complanatum, alpinum.* The spores of the Lycopods constitute what is vulgarly called Lycopodium powder or *witch-meal* (*Semen Lycopodii*).

(2.) *Selaginelleæ.* — Heterosporous; prothallia dicœcious, the male developing from the microspore, the female from the macrospore; leaves flat.

One genus, *Selaginella*, including two home species, *S. spinulosa*, *S. helvetica.*

B. PHANEROGAMS.

The vascular Cryptogams are distinguished by a well-marked constant *alternation of generations.* There are two of these generations, a sexual and an asexual.

The *sexual generation* is the prothallium resulting from the germination of the spore; it produces antheridia and archegonia, the latter containing an embryonic cell, from which, after fertilisation, arises the asexual plant.

The *asexual generation* is the vegetative plant, differentiated, as a rule, into root, stem, and leaves, the homologue of which is the sporogonium of the mosses. On this the spores are found in special spore-cases—sporangia—which arise from metamorphosed epidermis cells—hair-cells. Only in the highest groups are the sporangia to be looked upon as appendages of the leaves.

The *spores* of the lower vascular cryptogams are of one kind, and give rise to prothallia on which both antheridia and archegonia are produced. The higher vascular cryptogams (*Equisetums*) likewise produce but one kind of spores, but these give rise to two kinds of prothallia—male, upon which are to be found only antheridia, and female, on which are to be found only archegonia. The highest of all vascular cryptogams, again, produce two kinds of spores (macro- and microspores). The two kinds of spores are either found in the same sporangium, or the plant bears two kinds of sporangia, macro- and microsporangia. The result of the germination of the macrospore is a female prothallium, of the microspore, a male prothallium. In the Rhizocarpeæ the female prothallium protrudes from the macrospore, in the Selaginelleæ only the archegonium. In the latter the prothallium is developed within the macrospore, while that organ is still undetached from the parent plant.

Thus, while in the lower vascular cryptogams the two generations are sharply distinguished from each other, in the highest group matters are somewhat simplified by the fact that the sexual generation is partly formed *on the parent plant*, although fertilisation only takes place when the female prothallium has become detached.

In the Phanerogams the female organ is *fertilised*, and develops an embryo while still *on the parent plant. The microspores (male cells) produced by the Phanerogams are the pollen grains, while the embryo sac of the seed represents the macrospore (female cell)*. In the heterosporous vascular Cryptogams the two kinds of spores are always produced on the same plant; in many Phanerogams (dicœcious) one individual produces only microsporangia (anthers), another only macrosporangia (ovaries). In the highest Cryptogams only are the sporangia formed by leaves or homologues of leaves; in the Phanerogams this is always the case.

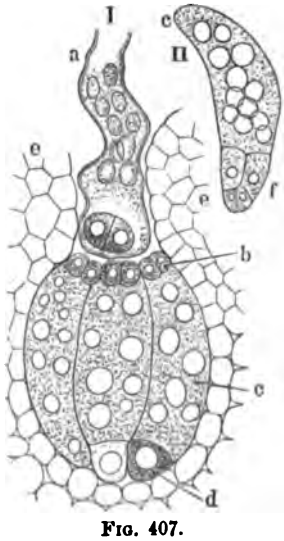


FIG. 407.

I. Corpuscula (*c*) of *Juniperus communis*. *a* Pollen-tube, *b* Apical cells of the corpuscula, *d* Embryonic cell, *e* Endosperm. II. Single corpusculum with protonema (*f*); 300 times enlarged.—(After Hofmeister.)

Series I.

ARCHISPERMS.

The microsporangia are borne on a separate shoot, similar to the spike of the Equisetums; they arise at the base of scale-like, shield-shaped leaves (antheriferous scales), and are termed *pollen-sacs*. Their wall consists of a delicate membrane, which, when the organ is ripe, opens by a vertical slit, and discharges the microspores (pollen-grains). The pollen-grain (Fig. 261, V., p. 165) is divided internally into three or four cells, which represent an extremely rudimentary prothallium.

The macrosporangia either stand singly, or are arranged in groups so as to form a spike (fir-cones). In the latter case they frequently arise in pairs in the axil of a woody bract (scale); they constitute the *ovules*. The macrospore is the *embryo-sac*, of

which there may be either one or several in a single ovule. The prothallium—the endosperm—formed from the embryo-sac produces archegonia or *corpuscula*. Of these there are usually several in each sac; they are not multicellular, like the corresponding bodies in the vascular Cryptogams, but unicellular (Fig. 407, *c*), except that where they come in contact with the apex of the ovule, two small neck-cells are formed (*b*). Fertilisation takes place as follows:—The pollen grains are carried by the wind to the female flower, where the pollen-tube (*a*) is protruded until it comes into contact with the corpuscula, its contents thereafter partially blending with those of the large embryonic cell. After fertilisation the basal cell (*d*) is formed from the embryonic cell, and from which by repeated division the pro-embryo arises (*f*). From this arise long tubes, which penetrate the endosperm. One of these develops into an embryo with radicle, plumule, and cotyledons, while the remainder are suppressed.

Type X.

GYMNOSPERMS.

The *Gymnosperms* constitute the sole type of the archisperms. The ovules are surrounded by an integument, but are not inclosed in an ovary. Leaves of peculiar shape and structure surrounding the shoot bearing the sporangium (*i.e.*, floral envelopes) are absent in the Gymnosperms. The foliage leaves are mostly needle-shaped, scale-shaped, or flat (Fig. 408), with very simple venation. The fibro-vascular bundles of the trunk are arranged in a concentric circle. Two orders—

(1.) *Cycadaceæ*.—Fern-like plants, with short unbranched stems, the surface covered with the scars of the fallen leaves; leaves clustered at the summit, large, pinnate, circinate in vernation like fern fronds; flowers dicœcious, consisting only of the sexual organs, arranged in terminal cones; fruit resembling a berry, sometimes red in colour.

Tropical plants, especially characteristic of the flora of South America; found also in the East Indies, Australia, and South Africa. Genera—*Cycas*, *Dion*, *Ceratozamia*, *Encephalartos*, &c. *Cycas circinalis* is a common hothouse species.

(2.) *Coniferæ* (*Pines*).—Trees or shrubs (408, I.), with simple, rarely pinnate (II.), scale-shaped (III.), or needle-shaped (Fig. 35, p. 24) leaves; ♀ flowers mostly in cones (Fig. 111, p. 65); fruit rarely a berry. Four families—

Fig. 408.

Flat leaves of Gymnosperms. —I. *Salisburia adiantifolia.* II. *Phyllocladus trichomanoides.* III. Scale-like leaves of *Chamæcyparis sphæroidea.* Figs. I., II., nat. size; III., four times enlarged.

a. Taxineæ.—Leaves alternate, frequently arranged in two rows; ♀ flowers not arranged in a cone, but consisting of a solitary naked ovule. One home species (*Taxus baccata*), the yew.

b. Cupressineæ.—Leaves opposite or in whorls; ♀ flowers forming a short, frequently berry-like cone. The juniper (*Juniperus sabina, J. nana,* &c.) is native to this country. The cypress (*Cupressus sempervirens*), a native of Southern Europe, and the Arbor-vitæ (*Thuja*), a native of China and Japan, are favourite ornamental species.

c. Abietineæ (*Pine-trees*). — Leaves alternate, often arranged in two rows; ♀ flowers forming an elongated, woody cone. *Abies excelsa, Abies pectinata, Pinus silvestris, Pinus Cedrus,* and *Araucaria,* and many others, are well-known species.

d. Gnetaceæ. — Mostly small shrubs, with opposite jointed branches and small leaves. Illustrative genera—*Ephedra, Gnetum,* and *Welwitschia.* The last-mentioned is remarkable for its two large simple leaves, which frequently attain a length of about five feet.

Series II.

Metasperms or Angiosperms.

The microspores are unicellular pollen-grains (Fig. 263, p. 168), from which a pollen-tube is protruded, and fertilises the unicellular archegonium. No female prothallium is found; the embryonic cell develops directly into the embryo; even an endosperm is rarely present. In the Metasperms the two generations of the vascular Cryptogams are represented by one, while in the Archisperms a rudimentary prothallium still occurs.

The macrosporangia (ovules) are mostly surrounded by a double integument, and by leaf-like organs, the carpels. These together form the ovary or protective covering for the young ovules, which is absent even in the Coniferæ.

The fully developed embryo (with plumule, radicle, and cotyledons, comp. p. 78) is enveloped by the two integuments, these together constituting the seed.

The organs in which the pollen and the seeds are developed (anthers and ovary) are surrounded by whorls of leaves, differing in form and colour from the foliage leaves, and constituting the floral envelopes (calyx and corolla); in some cases, however, the calyx and corolla are suppressed.

The two types of Metasperms, monocotyledons and dicotyledons, have already been described, the three first sections of this work having been almost entirely devoted to the consideration of their characteristic features. They not only claim the highest place in Systematic Botany, but are in reality the most highly developed members of the vegetable kingdom. In the number and variety of forms, especially in the number of individual families, they far exceed all other vegetable types. The latter—for example, the Equisetaceæ, the Lycopodiaceæ, the Selaginelleæ, and the Cycadaceæ—seem to have attained their most abundant development in past periods of the earth's history, and are now on the wane. In our own time the Phanerogams are in the ascendant.

ıs.

Floral envelopes absent or small, scale-like or chaff-like. Fruit a nut or caryopsis (rarely a berry), never a capsule.

…r herbs with broad …nate leaves; stem …pus or a caudex; …cence a *spadix,* …rge *sheath.* Fruit nut *or berry.*

Grass-like herbs with linear leaves; stem a round or triangular culm; inflorescence an *ear, panicle* or *loose corymb, without sheath.* Fruit a *caryopsis.*

…DICIFLORÆ.

GLUMACEÆ.

…erous and … tamens si… Calyx usu… corolla.

…opes …ale- …ous …pus. …stly …rm- … at …ich …ets, ♀. …y …ry- …ur-

Floral envelopes double, three-leaved. Ovary at first three-celled and three-seeded, *later one-celled and one-seeded, the rest becoming abortive. Fruit a nut or berry.* High trees with unbranched trunks; found only in the Tropics.

Flowers surrounded by glumes, *hermaphrodite,* with *two-leaved floral envelopes,* three stamens, and a one-celled, one-seeded ovary; *stigmas two.* Flowers in compound spikes or panicles. *Culm jointed, round.*

Flowers *hermaphrodite or unisexual. Envelopes absent,* or represented by *bristles* or an urceolate tube. Ovary one-celled, one-seeded, triangular. Stamens three. *Stigmas two or three.* Flowers in ears, or loose corymbs. *Culm triangular.*

…lowers monœ- …sule or

…alyx and …la of sa… …r (reddish, *…nens nine; …aries six,* …ny-seeded. …uit a dry *…apsule.* …ers herm… …hrodite.

…utomeæ.

Principes.

Graminеæ.

Cyperaceæ.

Carpels as many as the *petals and sepals;* ovaries five, four, or one-celled; when one-celled, the placentation is free central.

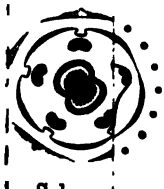
Ovary *one-celled, placentation free central; stamens united to the corolla,* and opposite to the petals. Floral whorls always pentamerous.

Ovary *several-celled,* placentation not free central; *stamens inserted on the receptacle.* Floral whorls tetramerous or pentamerous.

BICORNES.

Ovary *united* to the calyx, at first *inferior.* Fruit a *berry.*

Ovary *separate* from the calyx; at first slightly or altogether *superior.* Fruit a *capsule.*



Solaneæ.

Primulaceæ.

Vaccineæ.

Ericaceæ.

III.

everal-
in the

or *her-*

t in cat-
rushes.

rming a *perianth composed of several parts.*

Æ.

Ovary *superior*, floral envelopes *inferior;* comp. Table IV.

***

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xual; i
anicles c
rounded
ads; flo
nvelopes
tramerou
mens fou
ruit a *nu*
tigma on
Herbs.

present; ovary cells several-seeded; flowers *not* in umbels.

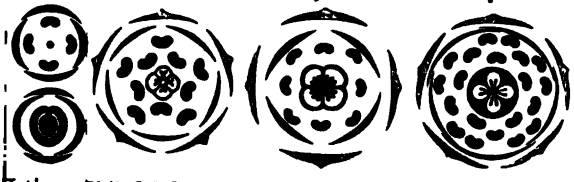
many-seeded *capsule* *berry.*

t-
in
u-

Fruit a *few-seeded pome;* calyx five-toothed, cup-shaped below; petals five, stamens twenty, united to the rim of the calyx.

Calyx and corolla *dimerous* or *tetramerous; stamens two* or *eight;* ovary four-celled and many-seeded, or two-celled and two-seeded. Fruit a siliqua or capsule; seeds elongated.

Ovary *three* or *four celled;* calyx tetramerous; petals four; stamens ten or *numerous.* Fruit a capsule.



Urticaceæ. Philadelphaceæ. Onagraceæ. Pomarieæ.

IV.

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Stamens five, seven, eight, or ten.

Stamens free.

Stamens properly ten, only seven or eight developed.

Stamens five, all fully developed.

ÆSCULINÆ.

FRANGULINÆ.

Corolla *symmetrical; stamens seven, of unequal lengths;* ovary *three-celled;* cells two-seeded. Fruit a *capsule.*

Corolla *regular; stamens usually eight, of equal length;* ovary *two-celled;* cells two-seeded. Fruit a *samara.*

Petals five or four, *small;* ovary two to four-celled; cells *one-seeded.*

Petals four or five, calyx small; ovary two-celled; cells *two-seeded.*

Ranu

Hippocastaneæ.

Acerineæ.

Rhamnaceæ.

Ampelideæ.

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